AGRICULTURAL RESEARCH INSTITUTE

PUSA

Proceedings of the American Academy of Arts and Sciences.

VOL. 61. NO. 1. DECEMBER, 1925.

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I. THE STELLATE CELLS OF *Juncus effusus*; II. CELLS OF HUMAN ADIPOSE TISSUE; III. STRATIFIED CELLS OF HUMAN ORAL EPITHELIUM.

BY FREDERIC T. LEWIS.

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PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES

VOL. LXI.

FROM MAY 1925, TO MAY 1926.

BOSTON:

PUBLISHED BY THE ACADEMY.

1926.

Intelligencer Printing Co.
Lancaster, Pa.

A FURTHER STUDY OF THE POLYHEDRAL SHAPES OF CELLS.

I. The Stellate Cells of *Juncus effusus;* II. Cells of Human Adipose Tissue; III. Stratified Cells of Human Oral Epithelium.

By Frederic T. Lewis.

Harvard Medical School, Boston, Mass.

Received May 7, 1925. Presented May 13, 1925.

I. The Stellate Cells of *Juncus effusus.*

In 1895 Herbert L. Jones, instructor in botany at Harvard, taught the writer to section the stems of Juncus and find the remarkable conjunction of six-rayed stars which constitute its parenchyma. That was in a course in which Professor George L. Goodale, M.D., reviewed, with easy urbanity, the founding of vegetable histology and the large part his profession had taken therein. If this further study of a well-known vegetable tissue proves worthy of such purpose, it is gratefully inscribed to the memory of these able and devoted teachers.

Apparently the pith of Juncus was first figured and described by L. C. Treviranus, physician in Bremen, in 1806. Malpighi had examined with a microscope the hollow stems of grasses; Hooke had looked into "some kinds of reeds"; Grew became involved in the thready lacework which he had "no where so well seen as in the bulrush, being cut transverse"; and in "Epistola 74" Leeuwenhoek had written "*De formatione Juncorum,*" but the rushes which he studied—"Junci seu Scirpi"—are shown by his admirable figures and description to be of the genus Scirpus, with pith of very different character from that under consideration. Possibly some eighteenth-century botanist saw for the first time these utricles in the form of stars, but it was Treviranus who made them generally known, by devoting to them the first two figures of his *Bau der Gewächse.*

In describing stellate parenchyma, Treviranus wrote that the fundamental form of cells is spherical, but if spherical vesicles, instead of expanding uniformly, should grow only at certain points while the rest of the surface remained stationary, radiate forms would result. "In the banana, *Musa sapientum,* the horizontal walls of the spaces

in the cellular tissue of the petiole consist of six-rayed cells everywhere connecting with one another by their rays, and so forming a net, the meshes of which are blunt triangles." "The same is true," he continues, "of the stems of *Iris pseud-acorus;* indeed the looser, spongy cell-tissue in *Juncus effusus* consists altogether of these radiate cells interconnecting by long thin arms." His little figure of Juncus pith is conventional and ineffective, but that of the banana is better, showing ordinary parenchyma on one side, and, in the center, an intermediate zone of transitional forms having rays that are very short and broad.[1] He recognized that spheres cannot be in contact with each other at all points (a feature which appears in no less than twenty of Grew's plates), and on examining parenchyma with this in mind he observed interstices of varying sizes—"*meatus intercellulares*" —everywhere intercommunicating and, as he believed, "containing sap." In the production of stellate cells these intercellular spaces enlarge.

A year later, in 1807, Dr. Rudolphi showed by simple experiments that air, and not sap, fills these spaces. Independently of Treviranus he refers, without figures, to the peculiar cells in the leaf-ribs of *Musa paradisiaca,* and in the leaves of Iris, etc. In the larger rushes (*J. effusus* and *J. conglomeratus*) he found a dry, papery and unusual pith where "little star-shaped diverging fibers (fine cells) form a loose and, under the microscope, very elegant network."

Link, writing also in 1807, commented on the air spaces which Mirbel (1802) has ascribed to the "tearing apart" of certain tissue due to strains from growth, and noted that their production may be especially well seen in the leaf-stalks of Canna.[2]

Moldenhawer, in 1812, found the stellate tissue in the banana "as Treviranus had described it." Since the investigation could not be carried out without grave injury to the plants, for several years he had cultivated them for the purpose. Intercellular spaces he described as primarily triangular, with sides bulging inwards, since they are arcs of circles. In the production of stellate cells these arcs must flatten and become reversed, finally being drawn toward the centers

[1] Comparable figures from Juncus have lately been published by Le Blanc,—Rev. gén. de Bot., 1912, vol. 24, pl. X, Fig. 5; and by Miss Snow,—Bot. Gaz., 1914, vol. 58, p. 511 (where the printer has transposed the blocks for Figs. 14 and 15).

[2] Mirbel's chapter, "Des lacunes," deals with a variety of unrelated spaces. They are said to be especially developed in aquatics, which have "plus d'embonpoint que de force réelle,"—"sehr drollig . . . flüchtig . . . ein schlechtes Buch" sputters Rudolphi.

of the adjoining cells until they form acute angles between the rays. This process, as Moldenhawer understood it, is well illustrated in Sir D'Arcy Thompson's drawing here reproduced as Fig. 1. But Moldenhawer could not agree with Treviranus that the rays grow out. The radiate figure, he declares, clearly arises through gradual dessication

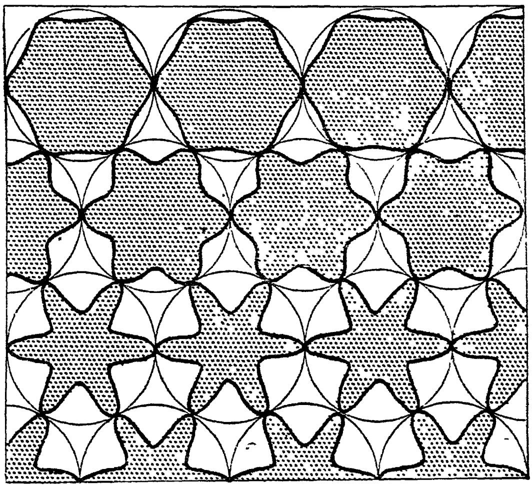

FIGURE 1. "Diagram of development of 'stellate cells' in pith of Juncus. (The dark, or shaded, areas represent the cells; the light areas being the gradually enlarging 'intercellular spaces.')"—Thompson, *Growth and Form,* 1917, Figure 133, p. 335. Courtesy of the University Press, Cambridge.

of the cells, shrinking to dry, sapless strands. He separated by maceration individual stellate cells of the yellow pond lily—which are, however, not comparable with those of Juncus—and by the same procedure demonstrated that young cells in leaves and cortex are almost spherical.

Kieser (1815) presents an inferior figure of the banana tissue and reviews the literature of stellate cells. Thereafter it is conventional to show the six-rayed stars in cross sections, with no provision for connections up and down the stem. Those of Juncus, for example, may be seen in Unger's "Grundzüge," 1846; in Quekett's "Lectures on Histology at the Royal College of Surgeons," 1852; in Schacht's "Lehrbuch," 1856; and in Brown's "Manual," 1874, where it is said that the same sort of tissue occurs in "the seed coat of the privet and the 'white' of the rind of the orange." Schleiden used similar in-

adequate figures for Aponogeton, but in a drawing of the spongiform tissue of Canna, he has made an interesting attempt to show the cells in their three dimensions. He states that they are irregular, and their form, as drawn, defies analysis.

In 1869, Duval-Jouve recognized that the form of a single stellate cell as a whole had never been determined, and that the manner of connection of the superimposed horizontal layers in Juncus was still unknown. He attempted to solve the problem and wrote:

> We have seen that at the time of their production these cells are spherical; consequently each of them is in contact, in the horizontal plane, with six others of the same layer, and vertically with three more in the plane below and three in the plane above. Now in their further growth and drawing apart, the cells retain their relative positions, so that generally they have twelve rays, corresponding to their twelve points of contact. Sometimes, often in fact, it happens that one of these points becomes detached and the ray is not drawn out. At other times, and still more frequently, the primitively spherical body is carried out between two rays, either vertically or horizontally, so that the rays seem to bifurcate. Such an occurrence, purely accidental, has been regarded as the usual disposition, and perhaps explains why they say,—'In *Juncus effusus* each ray bifurcates into obliquely directed branches which unite with neighboring cells, one a little above, and the other a little below.' I do not know who first expressed this opinion, which seems to rest on the idea that each cell has only six rays. With six undivided rays all union with cells above and below would be impossible,[3] and the sight of certain rays uniting toward a common center doubtless led to the notion that each ray is bifid. But that is a supposition . . . which ends in an impossible entanglement of the layers, inconsistent with any method of cell multiplication.

In a footnote Duval-Jouve shows that if cells with six bifid rays are arranged in horizontal layers, so that the upper branches of any cell, meet the upper branches of an adjacent cell lodged in the same horizontal layer, an impossible arrangement ensues, for in connecting with cells above and below, a *crossing* of strands would occur. The crossing, he points out, would be avoided if a cell with six bifid branches never united with an adjacent cell in the same horizontal layer, but only with one in a layer above or below. But if that were the actual arrangement, then, as he argues, a transverse section of Juncus should show six-rayed cells separated from each other by gaps equal in area to that of the cells themselves. Such is not the case, for, he declares,

[3] [Not necessarily! R. Brown, in 1874, wrote that "the rays are unbranched,—one or two being directed downward, the others upward, to join their neighbours." If alternate rays were deflected upward and downward for this purpose, a coherent pattern would be realized.]

the thinnest transverse sections show cells uniting by their rays with others *in the same plane.*

Apparently in agreement with Duval-Jouve is the more recent description by Sir D'Arcy Thompson. In 1917 he wrote:

> A very beautiful hexagonal symmetry, as seen in section, or dodecahedral, as viewed in the solid, is presented by the pith of certain rushes (e. g. *Juncus effusus*). . . . The cells are stellate in form, and the tissue presents in section the appearance of a network of six-rayed stars (Fig. 1, *c*) linked together by the tips of the rays, and separated by symmetrical, air-filled, intercellular spaces. In thick sections, the solid twelve-rayed stars may be very beautifully seen under the binocular microscope.
>
> What has happened is not difficult to understand. Imagine as before, a system of equal spheres all in contact, each one touching six others in the equatorial plane; and let the cells become attached at the points of contact. Then . . . let each cell contract by the withdrawal of fluid from its interior. The result will obviously be that the six equatorial attachments of each cell (or its twelve attachments in all, to adjacent cells) will remain fixed. . . .. As the final result we shall have a "dodecahedral star" or star polygon, which appears in section as a six-rayed figure.

Sir D'Arcy then explains that it is not so much shrinkage within a boundary of constant size, as a stretching apart of the cells after they have ceased to grow or to multiply, which produces the results in Juncus, and he concludes,—"The twelve-pointed star is still a symmetrical figure, and is still also a surface of minimal area under the new conditions."

Neither Duval-Jouve nor Thompson figures an entire cell, and both describe that twelve-rayed object as if it were derived from a rhombic dodecahedron. That shape was regarded as the typical form of parenchymal cells by all writers, apparently, until 1923. Sir D'Arcy Thompson had considered the tetrakaidecahedron as a possibility, but had rejected it in these words:

> Accordingly it is very probably the case that, in the parenchymatous tissue, under the actual conditions of restraint and of very imperfect fluidity, it is after all the rhombic dodecahedral configuration which, even under perfectly symmetrical conditions, is generally assumed.

Having found, on the contrary, that the cells of elder pith are tetrakaidecahedral, and assuredly not at all rhombic dodecahedral, the problem of Juncus became one of special interest. If derived from tetrakaidecahedral cells, should they not have fourteen processes, one for each tetrakaidecahedral surface? Or is the tetrakaidecahedral form found in some tissues, as in the elder, and the rhombic dodecahe-

dron in others, as in Juncus? What, after all, is the typical shape of an entire stellate cell? These questions, which I was led to investigate by reading Sir D'Arcy's admirable book, can be very definitely answered.

Material for study is easily obtained, *Juncus effusus* L. being widely distributed "in temperate regions of both the northern and southern hemispheres." The mature stalks which I collected were growing naturally within the city limits of Cambridge.[4] After stripping off the dense outer layers, the pith was preserved in alcohol; and when thoroughly imbedded in paraffin, it was cut in serial sections, both transverse and longitudinal, at various thicknesses.

On examining transverse sections 20 microns thick, it is seen at once that there is great irregularity in these cells. It is clear from what has already been said that the number of rays presented by a cell in transverse section is less than its total number of processes; and since the sections are but fragments of cells, it is unwise to lay too much stress upon the number of rays which appear. This number, for one thousand cells observed in transverse section, varied from three to eight per cell, as shown in the accompanying table:

TABLE I.

Number of rays per cell	3	4	5	6	7	8
Examples found among 1000 cells	6	74	323	469	117	11

The average number is here 5.6, and though six-rayed cells are more frequent than any other form, they fall short of making 50 per cent. of the cells examined. One of the more regular areas has been carefully drawn as Fig. 2, and it shows how far the conditions of Fig. 1, *c*, are actually realized. On leaving the cell body the rays quickly become reduced to a certain diameter which they maintain quite uniformly till they join another ray of the same diameter, at a place marked by a distinct cell wall, sometimes by a very slight constriction. Each arm may show a slight bulbous enlargement just before reaching the cell wall, but in Quekett's figure this inconstant feature has been greatly exaggerated.[5] Typically no two arms of any cell join two

[4] Professor Fernald has kindly determined that they are var. *solutus* Fernald and Wiegand (as described in Rhodora, 1910, vol. 12, p. 90).

[5] It is shown also by Brown. Large bulbous expansions where the arms of stellate cells unite have been figured in Eriophorum by Meyen.

arms of any other, so that the number of rays which a cell possesses indicates the number of other cells with which it is in contact; exceptions however are not infrequent.

The short cell wall where two arms unite may be divided in halves, much less often into thirds, by one or two minute pores, which sometimes appear as solid dots. Several of the cell walls in Le Blanc's figure of Juncus are provided with central dots, on which he makes no comment. Clearly they are undeveloped representatives of such larger cavities as he shows in Sagittaria and which are familiar also in Scirpus. In Brown's little figure of Juncus in cross section there are two instances of rays subdivided by the enlargement of these spaces, and in longitudinal sections I have seen a ray split for a long distance in this way. The parts reunite at either end, and whenever they occur, they join two cells by a double connection. In other plants the arms of stellate cells are often subdivided into many parts, so that a six-sided cell of Sagittaria, as Meyen described it, may produce no less than twenty-five rays to be seen in a single transverse section. The almost entire absence of this secondary splitting in Juncus contributes to its morphological distinction, since each process ordinarily means a contact with another cell.

The central body of the cell (Fig. 2) is discoid, with concavities between the conical attachments of the arms. Though primarily circular, or perhaps hexagonal with rays attached at its angles, it is often stretched out markedly in some one direction, as seen in an upper cell in the figure.

As a rule each ray is a member of a vertical pair, so that it may be described as bifid. At many places in Fig. 2, as at *a*, *a*, the roots of the paired processes are seen cut across as they pass out of the plane of section. The failure of certain lightly stippled cells to show any of them means that only the upper half of the cell is included in the section, and that the lower half of the disc, with its duplicating array of arms, has been carried away.

A glance at a vertical section of this tissue (Fig. 4) is sufficient to show Duval-Jouve's profound error in stating that adjacent cell bodies are in the same horizontal plane. In favorable places, as in that selected for drawing, a remarkably intricate pattern is revealed, in which hexagonal meshes are formed by the cooperation of four cells,—one above, one below, and one on either side. The top and the base of the hexagon are formed by the central discs of the top and basal cells respectively. Diverging arms of the lateral cells, joining arms from the top and basal cells, complete the hexagon. Often it is

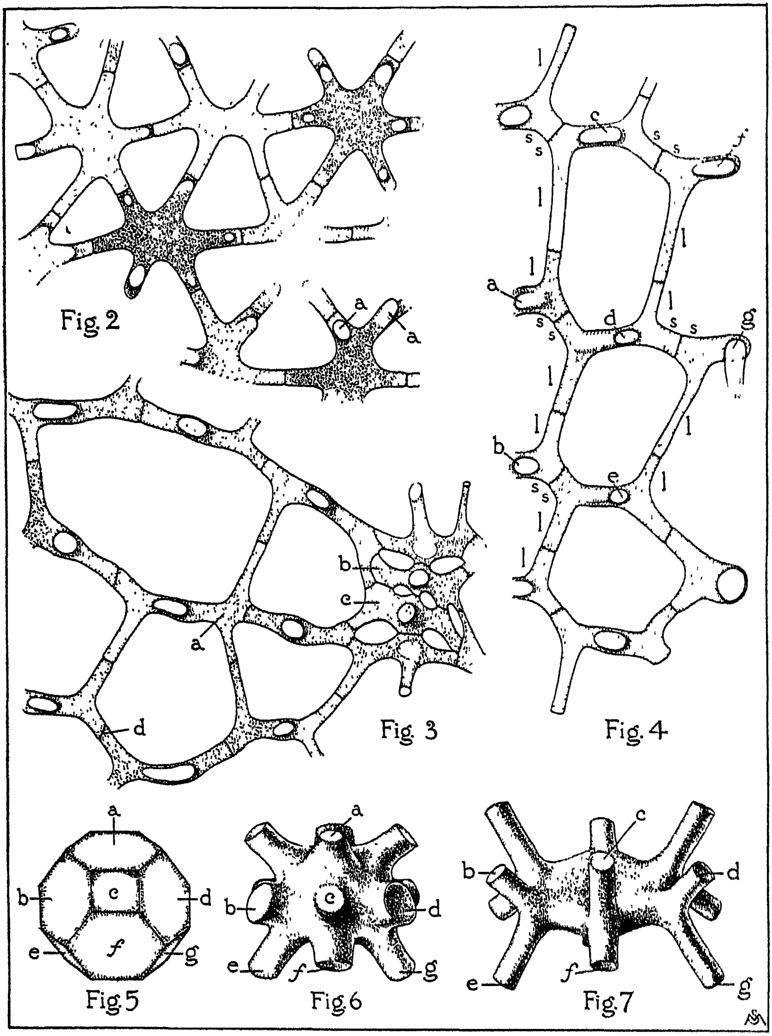

FIGURE 2. Stellate cells of *Juncus effusus* in a transverse section of mature pith. FIGURE 3. Vertical section from central part of the pith, showing irregular cells. FIGURE 4. Vertical section showing typical cells. (Figures 2–4 are from 20 μ sections, $\times$ 300 diam.)

FIGURES 5–7. Hypothetical models showing the relation of a typical stellate cell with all its processes (Figure 7) to the orthic tetrakaidecahedron from which it came (Figure 5), Figure 6 being an intermediate stage.

pulled into an approximately regular form as shown at the bottom of Fig. 4, where the lateral cells are nearly opposite one another, but that, as will be seen, is a distortion of the primary pattern. The upper portion of the figure shows more interesting conditions. There the level of the central disc of cell *f* is approximately one-third of the distance from *c* to *d;* and the level of cell *a,* two-thirds of that distance. The irregular hexagon formed by cells *c, f, d,* and *a* has long sides due to the union of two long arms, and short sides from the union of two short arms, the regular alternation of long and short arms being indicated by the column of letters *l, s, s, l,* etc. It will be observed that the cells *d, g, e,* and *b* form a similarly irregular hexagon. Finally it may be noted, on looking at cell *d,* that its upper arm on the right is long, and its upper arm on the left is short, the reverse being true of the lower arms. That should mean that two pairs of arms directed toward the observer have been cut away in this section; and two other pairs directed away from the observer are not seen. Having studied the cells in transverse and vertical sections to this extent, it is not difficult to construct a hypothetical model of a cell as a whole.

It is evident at once that the pattern could not have been derived from rhombic dodecahedra, for that involves such an arrangement of cells as Douval-Jouve described, which certainly does not exist. We have then to consider the possible relations to the tetrakaidecahedron, shown in Fig. 5.[6] Let intercellular spaces occur along all the edges, as if in a wooden model the edges had been followed and removed with a curved gouge. Let these grooves then be widened, especially at the corners, so that both the quadrilateral and hexagonal facets become circular. Then if these circular facets are drawn out at the fixed points of contact with other cells, the mass will take the form shown in Fig. 6. Further extension of the processes leads to the condition in Fig. 7, in which the vertical process *a* to the top facet and a corresponding one to the hidden basal facet have been arbitrarily omitted. The twelve lateral processes are of two lengths. Since the distance from the center of the tetrakaidecahedron to the center of a hexagonal facet (Fig. 5, *b*) is less than the distance to the center of a quadrilateral facet, *e,* there will be a short arm, *b* (Figs. 6 and 7), above a long arm, *e,* and *vice versa.* Moreover the six members of the upper and lower tiers of arms are alternately long and short as they

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[6] Figures of the tetrakaidecahedron from various points of view, and a detailed description of the tetrakaidecahedral cells of elder pith, are found in the report of which this is a continuation,—Proc. Amer. Acad., 1923, vol. 58, p. 537–552.

encircle the cell. The long arms, from the square facets, in becoming circular might be expected to be only four-sevenths the diameter of the short ones from the hexagons, and in the pith such a difference is often fully realized. But in general there is an equalizing tendency, so that commonly long and short arms are as nearly equal in diameter as those seen in Fig. 4. The cell walls often cross the arms obliquely as at *d* in Fig. 3. The theoretical extent and direction of this obliquity are shown in the diagram, Fig. 10, where a vertical section of a stellate cell has been inscribed within the corresponding section of a tetrakaidecahedron. The septa at the ends of all the arms, as there drawn, are oblique. In actual sections, an obliquity the reverse of that shown in the diagram is very rare, though the corresponding obliquity, sometimes exaggerated, is frequent. Ordinarily, however, it has been lost, and the septa cross the arms at right angles (Cf. Fig. 3).

Twelve lateral arms have now been accounted for, superimposed in pairs, so as to form a six-rayed star when viewed either from above or below; but if each tetrakaidecahedral facet produced an arm there should be two others, extending vertically from the central disc toward the top and basal surfaces respectively. If present in longitudinal sections, such as Fig. 4, they would form a straight vertical strand connecting *c*, *d*, and *e;* and unlike the lateral strands shown in the figure, the upward process from *e* would join the downward process of *d* without the intervention of any other cell. Such strands are seldom found in the longitudinal sections. In transverse sections, as in Fig. 2, if present, they would appear as sectioned arms rising from the midst of the central discs. Among a thousand cells examined for this purpose only ten showed evidence of a central process. It is evident, therefore, that if these stellate cells are derived from tetrakaidecahedra, their contacts with the cells above and below become severed with great regularity, so that the top and basal surfaces alone fail to produce arms.

The manner of the disappearance of the vertical arms may be studied in the longitudinal section, Fig. 3. Although taken from near the center of the pith, it shows on the right a succession of four cells which for some reason failed to separate with the rest. They have been stretched radially as much as their neighbors, but vertically they are still in connection with each other. Cells *b* and *c* join the cells immediately above and below them by means of short, low, conical processes, broadly truncate at the line of fusion with the inverted cone from the next cell. When these vertical processes are present they are usually simple cones, as in Fig. 6 at *a*. But in Fig. 3, cells

b and *c* have an unusually close connection with each other, the central cone being surrounded by a broad encircling attachment. To preserve the usual pattern (of the type shown in Fig. 4), *b* and *c* should be but a single cell. Evidently a late division occurred between them, shortly before the cells became stellate, and an extra cell interposed at this point kept the group crowded together at the critical time when the adjoining ones separated. There was a local diminution of the prevailing vertical tension, and also more material to resist it.

Another place where the elusive cause of the disappearance of the vertical arms may be sought is at the periphery of the pith, at the transition between stellate cells and ordinary parenchyma (Fig. 8, p. 17). A comparison of the heights of the two sorts of cells indicates that the stellate cells collapse above and below, perhaps by evaporation of their contents into the air spaces, as others have suggested. The vertical processes labeled *v. p.* connect with similar vertical processes which pass out of the drawing; but the unlabeled ones approaching each other in the middle of the figure do not meet. Their persistence after rupture indicates, perhaps, a late separation when the cell walls had become more viscid. Figures 3 and 8, to which many more might be added, are sufficient to prove that the vertical processes exist temporarily; and in perfected stellate cells it has been seen that they are lacking. Accordingly they have been omitted in constructing the hypothetical pattern, Fig. 7[7].

Several types of irregularities are to be expected. The suppression of a pair of superimposed arms accounts for the common five-rayed

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[7] The reason for their disappearance is fortunately not a part of the present problem. The upper and lower surfaces do not differ in size or shape from certain of the persistent lateral ones. They do differ in being in the plane of commonest cell division, which never occurs in the oblique planes of the lateral surfaces; but a new cell wall, if our interpretation of Fig. 3 has been correct, is not a place of special weakness. A greater vertical tension might account for the observed conditions, but there are certain difficulties, even if such greater tension be shown to exist.

With the loss of the vertical arms the typical intercellular space becomes itself a tetrakaidecahedral enclosure, which is bounded by parts of eight stellate cells. To picture an entire intercellular space, imagine a typical non-stellate tetrakaidecahedron oriented so that it has hexagonal surfaces above and below; and let these top and basal surfaces be connected with each other in vertical planes by six stripes bisecting the twelve lateral surfaces and preserving their inclinations, as if the stripes were painted on these surfaces. The stripes represent the arms of the eight cells bounding the intercellular space. Six of the central discs from which they come would lie in the horizontal planes where the lateral quadrilateral facets meet the lateral hexagons; the other two would be in the planes of the top and bottom hexagons of the 14-hedron which can be considered as filling the intercellular space.

stars, and still more frequent is the loss of only the upper or lower member of any pair. Although, for certain considerations to be presented later, the long arms might be expected to separate more often than the short ones, this could not be shown to occur. Certainly both kinds may be lost. Instead of bifurcating, a ray may divide into three superimposed branches, as at *a* in Fig. 3; or it may remain unbranched, like the ray joining the middle member of this trifid group. It can hardly be supposed that the regular alternation of long and short arms will be exhibited everywhere if the original tetrakaidecahedra are never typical (cf. the irregularities actually found in the cells of the elder), and in places of unusual tension the sections show conclusively that short arms may be stretched till long and slender. There are, therefore, irregularities perpetuating the atypical condition of the parent cells, and also new distortions and deficiencies added in the process of becoming stellate.

To determine whether the form shown in Fig. 7 is a valid and serviceable interpretation of the actual cells, a piece of cleared pith was examined with a binocular microscope, but it was impossible to follow all the processes with satisfactory precision. A wax reconstruction, at a magnification of 1000 diameters, was then made of a group of cells which had been cut in serial longitudinal sections at a thickness of ten microns. This group is shown as Fig. 20 (Pl. I), with the hypothetical interpretation beneath (Fig. 21), which bears all the lettering. The pattern is made of units like that shown in Fig. 7, except that where a process is lacking in the actual cells, it has been omitted from the pattern (or in a few cases indicated by dotted lines). There are five entire cells included in the group (*J*, *K*, *L*, *O*, and *P*), with the proximal halves of three others (*G*, *H*, *I*) and the distal halves of three more (*C*, *D*, *E*). Single bifid rays of seven other lettered cells are shown where they complete the mesh.

All five entire cells happen to have six rays each, but none has as many as twelve processes. Cell *L* lacks the upper median proximal, the lower median distal, and the lower right distal processes, which have been dotted in the pattern (Fig. 21) so as to indicate a complete cell. Cell *K* has apparently an undivided median proximal process, though after the loss of the upper or lower member of this pair, the remaining arm may have shifted to a central position, in which its origin cannot be recognized. This cell lacks also the upper right proximal process, having in all ten instead of twelve. Cell *J* is very similar, but retains only nine of its processes. Cells *O* and *P* lack two of the strands which would hold them together, and consequently

they have been drawn away from each other, making an unduly large hexagonal mesh. The lower left distal process of *O* and the upper left distal process of *P* (with an interconnecting arm of another cell) constitute one of the ties which is lacking. The other would be formed by the lower median distal of *O*, the upper median distal of *P*, and an interconnecting arm. In this case there is a knob on cell *O* which fails to connect with any other cell, and there is no evidence of imperfection in the series at this point. The knob is therefore interpreted as a vestige of the lower median distal process. In no other place in the group is there any trace of a process which has lost its connection with others, and so comes to have a free end. In both *O* and *P* the right proximal pairs of arms have been deflected proximally. *O* has nine processes, counting the knob, and *P* has ten. Considering the relative length of the arms, it is seen that *P* joins *L* with a short arm, and *K* with a long arm, just as in the pattern, but that on the right of the figure *P* joins *Q* with a long arm and *R* with a short one which is the reverse of the pattern. In other words *P* does not show consistently the alternation of long and short arms. In several places in the model the arms of a vertical pair are of equal length, and elsewhere reversals occur. Nothing could be more striking, however, than the way in which long arm joins long, and short arm joins short to make the right margin of the model.

The left portion of the model, which does not include entire cells, is instructive as showing the transformation of the pattern following the snapping of strands, and the production of elongated hexagonal meshes bounded by six cells instead of four. Cells *D* and *I* should be connected by arms as indicated by the dotted lines in Fig. 21; and *C* and *H* should have a similar connection which has not been dotted. The effect of the loss of these strands is sufficiently shown in the model as figured, and also the way that *F* acts upon *D* and *E*, pulling them together, unopposed by resisting strands which have dropped out.

From the study of this group of cells the hypothetical model is found to be a correct interpretation. It accounts for every one of the eighty-seven processes included in the group, and for their connections with one another. The stellate cells of Juncus are imperfect tetrakaidecahedral stars, in no way related to dodecahedra.

The origin of stellate parenchyma has been discussed by Miss Snow in a paper which I have found of great service. Origins can not be studied properly in mature stems alone, but it is not necessary here to pursue the subject further than that. Whether shrunken or not, the mature stellate cells of Juncus are very much smaller than the

parenchymal cells of the elder. Cut in any direction, an average stellate cell with all its branches can be drawn within the limits of a corresponding section of an elder cell at the same magnification. The volume of a stellate cell, as roughly determined by the displacement of the model, is .000033 c. mm., or one-thirtieth the volume of an average cell of elder pith. A mathematical calculation dependent upon the conditions shown in Fig. 10, the magnification of which is estimated by comparison with the sections, makes the volume .000022 c. mm. There are serious errors by either method, but it is clear that the relative volume is very small. The large cells of the elder are under pressure and expand when released from the stem (Jost); stellate cells on the contrary may be under tension, as Le Blanc showed for Pontederia, by puncturing the tissue with a needle and observing that the cells retracted. But it can not hastily be concluded that the cells of Juncus are shrunken, since in the mature stems, at least, there are no surrounding cells large enough to produce them in that way.

The sizes of these surrounding cells and of the stellate cells in contact with them are shown in Fig. 8, below which the section of a stellate cell from further within the pith has been drawn at the same enlargement. By comparing these figures, it is seen that the vertical diameter becomes actually and permanently decreased as if by shrinkage; but all other dimensions are increased. The arms may become four times as long, and the radius of the central disc is doubled. If the cells which give rise to the central cells were as small as those at the periphery, there is not merely a redistribution of the substance of the original cell under tension, but a certain amount of actual growth. This may not be very great, for the material within the inner tetrakaidecahedron, half of which is drawn in Fig. 10, is equal to that in the radiate stippled cell shown sectioned in the same figure. Growth under tension is the accepted method for the production of these cells, and it seems to occur.

The stellate cells seldom divide, and whenever they do so, the pattern is permanently altered. The simplest vertical division would produce a pair of cells with four rays each,—one undivided, by which the two cells would connect with each other, and three of the ordinary bifid sort. I have seen a perfect instance of this. Horizontal division gave rise to the pair of cells already described in Fig. 3; if such cells should move apart, they would retain connections with each other by one or more vertical arms.

It is a significant fact that the meshes do not become gradually larger toward the center of the pith; on the contrary they are subject

to similar variations throughout the mass except in the narrow transitional zone at the periphery, where their diminution in size is considerable and abrupt. This may be explained if new stellate cells are added peripherally, and perhaps at the diaphragms, so as to moderate the tension due to the rapid growth of the outer layers of the stem.

Functionally this elaborate tissue has been regarded as an aerating device, comparable with the simply hollow stems of grasses. Whether it serves also as a trusswork contributing to the rigidity of the stem can be answered by such experiments as Professor P. W. Bridgman has kindly outlined and reviewed for me. In making the measurements I have been assisted also by Mr. B. J. Anson. Sachs once commented on the remarkable rigidity of the stems of "grasses, many rushes and sedges," whereby the slender scape, driven by the wind, "may be bent down into a semicircle . . . and spring up again like elastic steel wire." A very different tissue is chiefly responsible for this, yet Schwendener, without experimental evidence, regarded the stellate cells as contributory. The pith of Juncus may readily be forced out of a piece of stem 10–15 cm. long by using the terminal part of the culm of timothy (*Phleum pratense*) as a plunger. (This hollow-stemmed grass proves to be four times stiffer than the stellate-pithed Juncus, volume for volume, using Young's modulus for this comparison.) In removing the pith from Juncus stems 2 mm.–3 mm. in diameter in this way, the pith is sometimes compressed to one-fifteenth of its original length. When released it may spontaneously return, or easily be stretched, almost to the length of the stem from which it came. But it can not be stretched much beyond that point without transverse rupture. For example, a piece of pith 10 cm. long and 2.5 mm. in diameter could be stretched only to 10.5 cm. by a weight of 20 grams, when it snapped. The breaking point of pith of this diameter, as determined by attaching, by means of wire and paraffin, a pan of weights to its lower end, ranged from 15 to 40 grams. But the freed pith, very compressible though only slightly distensible, may readily be doubled upon itself, or closely coiled, without apparent rupture—all of which properties, except its resistance to a longitudinal pull, might be expected from its structural arrangement. Its part in maintaining the rigidity of the stem against bending to the breaking point was tested as follows. Intact stems were clamped at one end by pouring melted paraffin around them, and a weight carrier was suspended from the horizontally projecting part at a point 10 cm. from the clamp. Weights were added until the stem bent sharply downward, collapsing at the clamp. The pith was then pushed out

and the experiment repeated, using the same stem just beyond the place previously injured. Though the pith forms two-thirds of the volume of these stems, it constitutes only one-twelfth of their weight, and the removal of the spongy core has surprisingly little weakening effect. A stem 10 cm. long and 3.2 mm. in diameter which broke under a weight of 15 grams when its pith was intact, supported weights up to 14.3 grams after its pith had been removed. The stellate tissue is therefore unimportant in giving strength to the stem, both because of its central position, and its low elasticity, which is about twenty times less than that of the rush as a whole. Moreover the rigidity of the entire stems is not great, since, weight for weight, it is over five hundred times less than that of steel wire.[8]

The ancient conclusion that vegetable cells "enclose the greatest mass with the least surface" (Kieser, 1818) is not applicable to the stellate cells. Their mass is no longer the maximum for the surface area, but under the conditions imposed, the surface area is apparently still minimal. The necessary calculation has been made for me by Professor Harvey N. Davis, to whom I am greatly indebted, not only for this, but for many other suggestions from the point of view of the mechanical engineer. If the section of a stellate cell be inscribed geometrically within that of an orthic tetrakaidecahedron, as in Fig. 10, and the diameter of the arms be made one-fourth of AB, then, if the surface of the stellate cell is to be minimal, the radius of the central disc, according to Professor Davis, should be 0.58 of AB. The comparison of such proportions, stippled in Fig. 10, with those of an actual cell (Fig. 9), leaves no doubt that in the production of stellate cells we are dealing with a minimal-surface phenomenon. Professor Davis discusses the problem as follows:

First, we assume that the arms of a stellate cell meet those of other cells in

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[8] Professor Bridgman supplies the following data. The values for Young's modulus are:

For timothy, stem as a whole, $E = 1.27 \times 10^9$ Abs C.G.S. (bending experiments)

For rush, stem as a whole, $E = .30 \times 10^9$ Abs C.G.S. (bending experiments)

For rush, pith only, $E = .016 \times 10^9$ Abs C.G.S. (extension)

The comparison with steel is made as follows: E for rush is 3×10^8 Abs C.G.S.: E for steel is 21×10^{11}. The density of the rush (sp. gr. = .63) is one-twelfth that of steel. If the density of steel were one-twelfth as much, its E would be $\frac{21}{12} \times 10^{11} = 1.75 \times 10^{11}$. Hence the elasticity of rush is $\frac{1.75 \times 10^{11}}{3 \times 10^8} = 583$ times less than that of steel on a weight for weight basis.

points corresponding with the centers of the surfaces of an orthic tetrakaidecahedron (in section, Fig. 10, at C and D), each arm acting as if it were attached to a small circular disc pivoted at one of these fixed points; and second, we assume that the internal volume of each cell is much smaller than that of the tetrakaidecahedron which it occupies, either because of evaporation of liquid from the interior of the cell, or because the inscribing tetrakaidecahedron has been stretched by the growth of other parts of the plant, or both. And finally, we assume that the cell-wall acts like a stretched membrane, or like the free surface of a liquid or of a soap-film. Under these assumptions the cell-wall will take the shape that has least surface for a given volume, while at the same time maintaining contact with adjacent cells at the prescribed points C, D, etc.

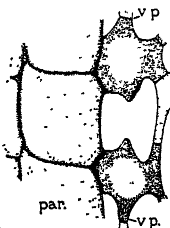

Fig 8

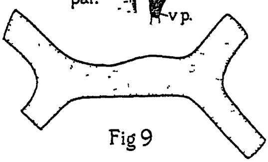

Fig 9

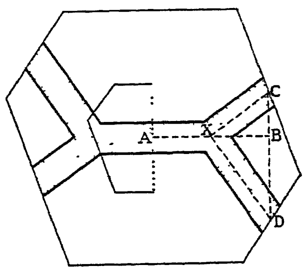

Fig. 10

FIGURE 8. Stellate cells at the periphery of mature pith of Juncus, in contact with unmodified parenchyma, *par.* *v. p.*, vertical process. × 500 diam.

FIGURE 9. Exact outline of an actual section of a stellate cell (× 500 diam.) for comparison with the diagram in Figure 10.

FIGURE 10. Section of an orthic tetrakaidecahedron within which is inscribed the corresponding section of a stellate cell, geometrically constructed, of minimal surface. The volume of the entire stellate cell is two twenty-thirds that of the surrounding 14-hedron. On the left of A, one-half of a 14-hedron has been outlined, in volume equal to that of the stellate cell.

If the areas of contact at C, D, etc. and the cell volume are given, there doubtless is one and only one surface satisfying these conditions, but a rigorous mathematical derivation of its shape would be extremely difficult. We may, however, at least partly justify our belief that the shape of a stellate cell is indeed determined by the conditions just described, and by them alone, by the following approximate computation.

Let us assume that the surface of a cell is roughly the same as that of two hexagons (corresponding to the upper and lower faces of the central body of the cell) plus the lateral surfaces of six long and six short cylinders (corresponding to the twelve arms). Let us further assume that the length of each

short arm is CX in Fig. 10, that the length of each long arm is DX, and that the radius of the circle in which each hexagon could be inscribed is AX. This assigns to each arm a little more area than it actually has, but this is more or less balanced by our neglect to include any area corresponding to the edges of the hexagonal plate in the center. Finally let us assume that the diameter of each arm is some known fraction of the distance AB in Fig. 10. Then there will be a definite distance AX which makes the surface as thus described a minimum, and this distance will be greater for arms of large diameter than for arms of small diameter, as shown in the following table:

Ratio, diameter of arms to AB	Ratio, AX to AB
0.1	0.291
0.2	0.504
0.25	0.580
0.3	0.638

In determining these dimensions we have not attempted to differentiate at constant volume, as our assumptions demand, because there seems to be no easy way to take account of the presumably variable thickness of the central disc. Nevertheless, the fact that there is a shape that makes our crude approximation to the surface of a cell an absolute minimum, and the further fact that the shape thus determined (say with diameter of arms one-fourth of AB) agrees as well with the observed facts as could reasonably be expected, lead us to believe that we are really dealing with a shape of minimal surface under the peculiar conditions postulated above.

It may be noticed in passing that if this hypothesis is correct, the contents of a stellate cell must have been continuously under a partial vacuum, due to the tension in the slightly inwardly concave upper and lower surfaces of the central body during the whole period in which the shape of the cell was being determined by the forces here considered. [Distinct concavity of these surfaces is seldom evident, perhaps owing to the absorption of the vertical processes.] It may also be noticed that under these assumptions it is impossible that the stellate cells should have thrust each other apart by their own growth. It is necessary either that their surroundings should have grown too fast for them, thus pulling them away from each other, or that their internal volume should have shrunk very considerably after their distances apart had been determined by their early growth while still in tetrakaidecahedral form. In any case there must have been tension along the arms when the stellate form was attained.

II. Cells of Human Adipose Tissue.

"In well-nourished bodies, the fat-cells"—as Schäfer remarks—"where packed closely together, acquire an angular figure, and bear a striking resemblance to the parenchymatous tissue of plants." Their shape resembles that of elder cells in cross section, and they approach

them in size. At the corners, where the plant cells have air spaces to supply them with oxygen, the fat-cells have blood vessels. There are, however, certain differences. The cells of adipose tissue have a random arrangement so that transverse and longitudinal sections are indistinguishable, whereas the parenchymal cells are definitely oriented. This is because the latter have arisen by regular division of preëxisting tetrakaidecahedral cells. Fat-cells presumably do not divide. They arise by the formation of fat droplets in cells which at first have no contact with each other, except through slender filamentous processes. When these cells become distended and reduced to mere films surrounding the spherical fat droplets within, they *acquire* contacts with each other and become facetted. Do they take the shape of peas which by enlargement in a limited space become facetted? Not at all. The resemblance to parenchymal cells proves closer than was anticipated.

A lobule of subcutaneous fat from the abdominal wall, preserved in formalin, was cut in serial sections ten microns thick. An area from one of these sections, including some of the cells modeled, has been drawn as Fig. 11, at the same magnification as the longitudinal section of elder pith figured in these Proceedings, vol. 58, p. 543. In both cases the numeral within each cell indicates the number of contacts which that cell has with other cells. This can be determined by following the cell from beginning to end through the series. One hundred fat-cells were studied in that way and the results are tabulated in Table II.

TABLE II.

No. of Surfaces	9	10	11	12	13	14	15	16	17	18	19	20
No. of Cells	2	4	5	15	13	20	15	17	4	2	2	1

The figures in the lower row show how many cells, among the one hundred counted, exhibited the number of surfaces indicated at the top of the column. The average number of surfaces is 14.01. For one hundred cells of the elder the average was 13 96.[9]

Eleven cells were reconstructed in wax, magnified 500 diameters. Ten of these were chosen at random. The eleventh was selected because of its unusual shape. It seems to have been flattened and even hollowed out by pressure from its spheroidal neighbors. This

[9] Cf. Table I, Proceedings, vol. 58, p. 544.

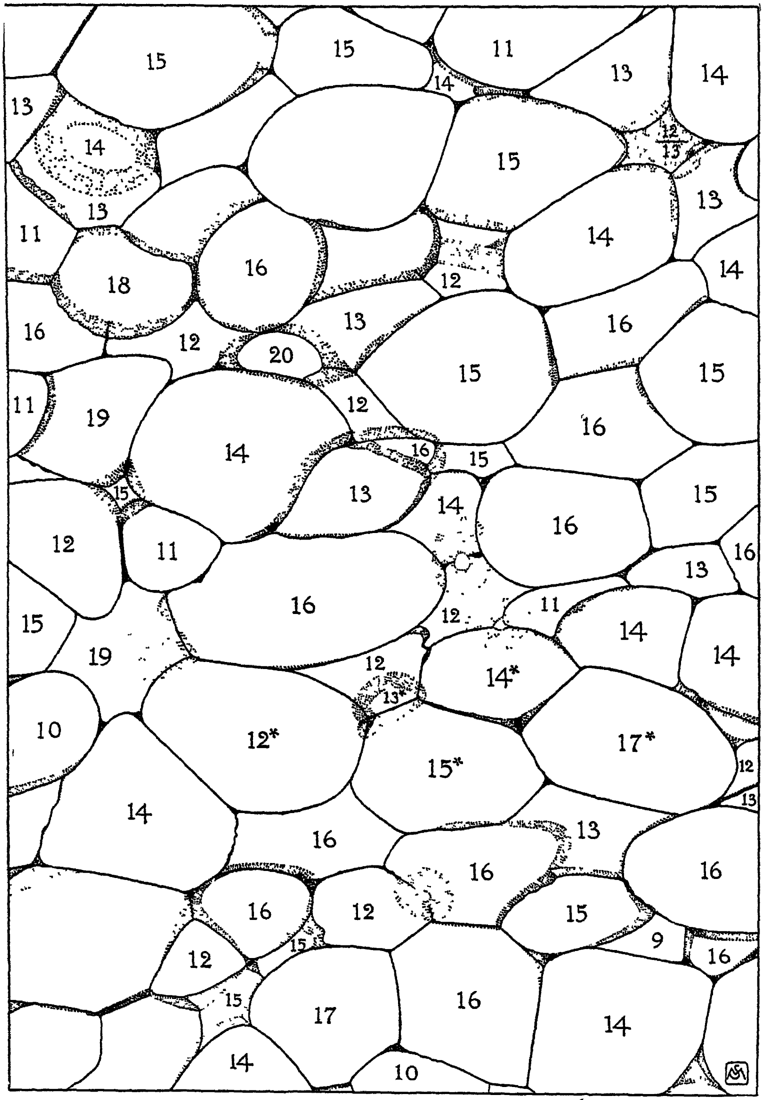

FIGURE 11. Section of human adipose tissue. × 220 diam. The numeral in each fat-cell indicates the number of contacts which that cell has with other cells. Two numerals on a septum indicate the contacts of the cells above and below the septum. Cells marked with an asterisk appear in the group, Figure 26, Plate II.

nondescript cell is shown in Fig. 22, Pl. II. Its volume (.00024 c. mm.) is somewhat less than that of any of the ten of normal shape, but its surface is by no means minimal and it is in contact with seventeen cells. If it had developed normally and then, for some reason, fat had been withdrawn from its interior, such a condition might follow.

The volume of the ten normal cells ranges from .00028 c. mm. to .00095 c. mm., with an average of .00048 c. mm., which is close to one-half the average volume of elder cells. In form the fat-cells are more nearly isodiametric, and their lack of definite orientation, which in the elder provides an obvious top surface and base, makes them more difficult to study. In the cell shown in Fig. 25, however, the tetrakaidecahedral pattern is strikingly exemplified, at least in the half of the cell shown in the drawing. This is a cell with thirteen surfaces. The one taken as the top is hexagonal; the base deviates in being pentagonal, but the six lateral surfaces shown in the figure are alternately quadrilaterals and hexagons, precisely as required by the exacting pattern. The remaining lateral surfaces (five instead of six) are all pentagons.

Another approach to the typical arrangement is shown in Fig. 24—a cell with fourteen surfaces. The top and base are both hexagonal. As oriented in the figure, three of the lateral surfaces are typical—being two hexagons and a quadrilateral properly alternating—and three are pentagons. Instead of presenting altogether 8 hexagons and 6 quadrilaterals, this cell has 6 hexagons, 4 quadrilaterals and 4 pentagons. The occasional substitution of pentagons for alternating quadrilaterals and hexagons was noted and described in the elder. In adipose tissue it seems much more frequent. The total number of surfaces for ten typical cells should be 140,—60 quadrilaterals and 80 hexagons. The surfaces of the ten cells modeled (141 instead of 140) were,—2 triangular, 30 quadrilateral, 74 pentagonal, 33 hexagonal and 2 heptagonal. The substitution of pentagons, however, cannot be carried out uniformly, for the resulting cells, hexagonal above and below, with twelve lateral regular pentagons, would be unstackable.

What happens when pentagons are substituted is shown in the diagram Fig. 12, reproducing the proportions of an actual cell. In *A*, the arrangement of quadrilaterals and hexagons is typical. In *B*, the two quadrilaterals on the right have enlarged at the expense of the hexagons, producing a tetrahedral angle at *b*; a further enlargement of the same facets makes four pentagons as in *C*. Such a shifting of boundaries as this involves is a very familiar feature both in the seg-

mentation of the ovum and in its experimental simulation with soap bubbles. Turning to the left of Fig. 12 *A*, it may be noted that the cell (not pictured) which meets the left edge of the quadrilateral surface, forms also the left upper edge of the hexagon below it. If that cell became smaller, the left upper edge of the hexagon would diminish until a tetrahedral angle would occur at the point *a* in Fig. 12 *B;* with still further reduction, that point would be passed, and all the lateral surfaces would be pentagons as in Fig. 12 *C*. The actual cell shown in Fig. 23 has the tetrahedral angle of Fig. 12 *B*, *b*, and, on the left, the pentagons of Fig. 12 *C*. As a whole this cell has 13 surfaces, —4 quadrilaterals, 1 hexagon, and 8 pentagons.

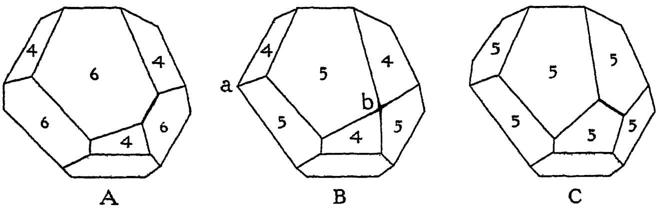

FIGURE 12. Diagrams based upon the model pictured in Figure 23, Plate II, showing the transformation of quadrilateral and hexagonal facets into pentagons.

Tetrahedral angles are regarded as unstable and geometrically they may not exist, but when it becomes impossible to determine in which of the alternative ways they should be resolved into a pair of trihedrals—when the line connecting the two trihedrals becomes so short that it cannot be seen—a tetrahedral angle has been assumed to occur. The ten cells modeled present 234 angles, of which 225 are trihedral and 9 are tetrahedral in the sense stated. Three of the tetrahedral angles occur on one very large cell with 20 surfaces, and altogether 33 angles (instead of the normal 24). It is shown in the lower right corner of Fig. 26.

The group of fat-cells shown in Fig. 26 is especially well modeled and admirably drawn.[10] It is a figure which becomes of interest in comparison with a similar group of elder cells and their interpretative pattern (Proc., vol. 58, Pl. III). If the fat-cells were typically shaped and arranged, the socket on the right from which a cell has been dislodged would have a hexagonal instead of a pentagonal base, and would

[10] The models, it should be recorded, were all made by Ethel S. Lewis, and the drawings by F. Schuyler Mathews, whose skilful work, in different ways, has been indispensable in making this study intelligible.

be surrounded by alternating hexagons and quadrilaterals instead of by the surfaces shown and numbered. Traces of the typical pattern are there, but the deviations recall Hooke's apology for the form of snow crystals, which if not "vitiated by accidents" would exhibit "abundance of curiosity and neatness."

Avoiding all the labors of reconstruction, objects quite like the models of fat-cells, with clear-cut facets, many of them pentagonal, may be seen on looking at a smear of the yolk granules from a hard-boiled egg, then in crumbly condition. Seen in reflected light, it becomes a surprising display, which the ill-starred Pouchet figured handsomely in his "Théorie positive de l'ovulation spontanée" (1847, Pl. XI). He describes the polyhedra as having "ten to twenty facets irregularly disposed" and although he says that under proper conditions "on aperçoit parfaitement leur configuration," he does not subject it to any analysis.

In concluding that yolk granules and fat cells are the tetrakaidecahedral products of piling spherical bodies, it is well to consider what sort of piling must take place for that result. This is shown in a diagram which I planned but could not construct without the aid of a geometrician. Professor William C. Graustein has most generously made the necessary calculations, which show some unexpectedly interesting relations. The importance of his contribution in what follows is very gratefully acknowledged. Spheres arranged as in Fig. 13 *A*, by compression become cubes (Fig. 13 *B*) with edges 1.61 times the radius of the sphere and a surface area 1.24 times as great. The normal piling of spheres—the arrangement taken by peas thrown together in a heap—is shown in Fig. 14 *A*, leading to rhombic dodecahedra when compressed, Fig. 14 *B*. The length of the edges of the rhombic dodecahedron is 1.11 times that of the radius of a sphere of equal volume; and the surface area becomes 1.1050 times that of the sphere. The orthic tetrakaidecahedron, with plane surfaces, has edges which are all of equal length, namely .72 of the radius of a sphere of equal volume; its surface area is 1.0987 times as great. "The surface area of the tetrakaidecahedron is 58/100 of 1 per cent. less than the surface area of the rhombic dodecahedron of the same volume," Professor Graustein reports, and to maintain such an advantage toward a minimal surface, the spheres must arrange themselves as shown in Figs. 15 and 17, combining, it will be seen, features of both the cubical and dodecahedral piling.

Viewed in a certain plane the spheres are arranged as in Fig. 13 *A*, yet so spaced that each is separated from the four which surround it

by .31 of the radius of the sphere. This is shown in Fig. 15. Sphere *E*, upon compression to make a tetrakaidecahedron, will acquire quadrilateral facets with *B*, *F*, *H* and *D*, and with two spheres not seen in this plane, *R* and *S*, above and below it respectively, likewise separated by .31 of the radius. Thus the six quadrilateral facets of the tetrakaidecahedron are produced from spheres not immediately in contact with it. Its eight hexagonal facets proceed from immediate contacts. Let a sphere be dropped from above into the interval between *D*, *E*, *G* and *H*. It will come in contact with all of them, and by compression will give to each a hexagonal facet as shown in Fig. 16. Similarly sphere *O*, not seen in Fig. 15, rises up directly beneath *N*, but can not reach it, the separating distance being .31 of the radius. This is shown in Fig. 17, which passes through the centers of *G*, *E* and *C* of Fig. 15 in a plane perpendicular to that of the printed page. *J-K*, *L-M* and *P-Q* in Fig. 15 indicate the positions, above and below respectively, of the remaining cells which provide the fourteen surfaces of *E*.

The arrangement of spheres in Fig. 17 is comparable with that in Fig. 14 *A*, but they have been spaced apart in a very definite manner. A line has been drawn through the centers of *N*, *E* and *M*, and where it forms the diameter of *M* it has been divided into sixths. The center of *S* projected upon it, arrives at the junction of the first and second sixths; and the center of *C* at the junction of the fifth and last sixths. More serviceable in cytology is the correlated fact that the tangent between *L* and *C* meets the junction of the first and second thirds of the diameter of *M*; and the tangent between *S* and *X* meets the junction of the second and last thirds.

Compression of the spheres in Fig. 17 produces tetrakaidecahedra as seen in Fig. 18, where *E* is shown in relief. The axis of symmetry is vertical, but the vertical axis of the stem in the elder and in Juncus is the line *N E M* of the figures. In other words the cells in pith are so arranged as to have three axes of symmetry, diverging from each other at angles of 120°, and each of them tending across the stem at angles of 54.73° with the vertical (the tangent of this angle being $\sqrt{2}$). In adipose tissue no such axes can be made out. The fat-cells, with an average of 14 sides and therefore very properly called tetrakaidecahedra, deviate so much from the orthic form that it seems questionable whether we can assume for them any such complex origin as that which has been described, in order to gain toward the minimal surface area a fraction of one per cent.

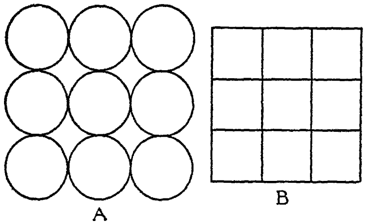

Fig 13

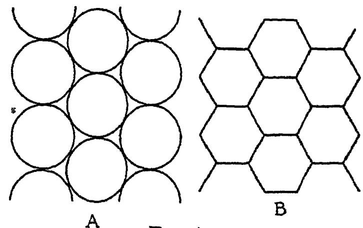

Fig. 14

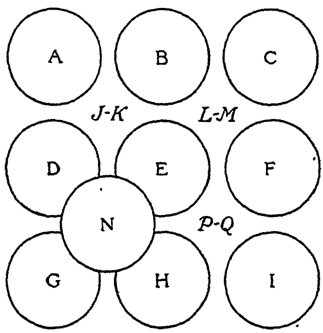

Fig 15

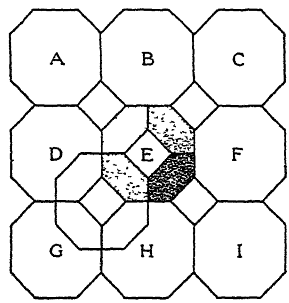

Fig 16

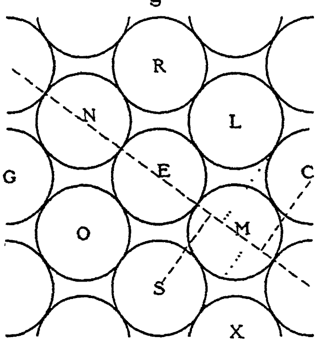

Fig 17

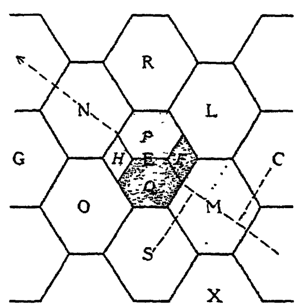

Fig. 18

FIGURE 13. Spheres of the size and arrangement in *A*, by compression produce cubes of the size in *B*. FIGURE 14. Spheres as in *A* produce rhombic dodecahedra in *B*. FIGURE 15. Spheres arranged for producing 14-hedra. FIGURE 16. 14-hedra from the compression of the spheres in Figure 15. FIGURE 17. Spheres arranged for producing 14-hedra as seen in a plane passing through *G N E C* of Figure 15 perpendicular to the plane of the page. FIGURE 18. 14-hedra from the compression of the spheres in Figure 17.

To test the question whether the ten fat-cells already described as irregularly shaped, are so formed to maintain a minimal surface area, the surfaces of the models were measured with a planimeter. In Table III the volume of each cell, enlarged 500 diameters, is recorded, together with its surface area. The surface area of an orthic tetrakaidecahedron of the same volume has been calculated by Professor Graustein who established the following formulae, in which a is the length of the edge of a tetrakaidecahedral surface. The volume and area of the tetrakaidecahedron are respectively:

$$V = 8\sqrt{2}a^3 \qquad A = 6(2\sqrt{3} + 1)a^2$$

or approximately:

$$V = 11.314a^3 \qquad A = 26.785a^2$$

TABLE III

Fat-Cell	Volume (cubic inches)	Surface (square inches)	Surface of orthic 14-hedron of same volume	Percentage which measured surface is of theoretical
A	2.16	8.77	8.89	98.7
B	2.42	8.74	9.58	91.2
C	2.67	9.77	10.23	95.5
D	2.70	10.30	10.31	99.9
E	2.77	10.55	10.49	100.6
F	3.33	11.30	11.85	95.4
G	3.40	11.58	12.03	96.3
H	3.94	12.87	13.26	97.1
I	5.18	15.06	15.92	94.6
J	7.32	19.10	20.04	95.3

There are many sources of error, but after the volumes and surfaces had been determined as accurately as possible, with no idea at that time of what the minimal surface should be, the figures were not revised in any way. In only one instance is the actual surface area greater than that of the mathematically perfect pattern. In the other nine cells the area is less, showing that by substituting pentagons for hexagons, and through other irregularities, better results are obtained than any uniform pattern allows. The average surface area of the ten cells is 96.5 per cent. of that of perfectly formed tetrakaidecahedra.

Since the rhombic dodecahedron has 14 angles, the question naturally arose whether the spheres may not pile in the normal manner (as in Fig. 14) and after compression into rhombic dodecahedra, by sub-

sequent truncation, be transformed into tetrakaidecahedra. To this Professor Graustein replied as follows:

> It seems hardly possible that the *regular* 12-faced solid can be made into the regular 14-faced one by simple truncations without cutting away all the vertices and faces. . . . I feel reduced then to the combination of a truncation and a distortion. The 6 tetrahedral angles are truncated by planes, leaving an 18-faced solid with 6 square and 12 hexagonal faces. Four of the hexagonal faces must be done away with. This is accomplished by choosing four square faces which are opposite in pairs, and hence perpendicular to a plane, and shrinking these faces to edges by bringing the sides of them which are parallel to this plane to coincide. In this way four hexagonal faces reduce to square faces, taking the place of the square faces which have disappeared.

No indications of this transformation have been found. If the tetrakaidecahedra are not transformed dodecahedra, it follows that the complex type of piling shown in Figs. 15 and 17 actually occurs, due to the great resistance of the fat-cells to any deformation which increases their surface area. Varying greatly in size when the piling takes place, the resulting tetrakaidecahedra are indeed irregular.

III. Stratified Cells of Human Oral Epithelium.

Less promising and more difficult is the study of the smaller cells in stratified epithelium. The specimen chosen was from the particularly thick layer which extends from the corners of the mouth along the inside of the cheeks, in a human embryo of about five months. The serial sections were four microns thick; and certain cells were modeled at an enlargement of 2000 diameters. For purposes of orientation, an outline drawing at the same magnification as that of the fat-cells (Fig. 12) is presented in Fig. 19. The basal and formative layer is composed of the smallest cells, with walls so thin that Schwann and others at first believed them lacking. The walls are there, but in sections as thick as these, it was found impossible, after many attempts, to follow any basal cells in the way requisite for wax reconstruction. It became quite clear, however, what their shape is. They are six-sided, as a rule, in transverse section. Toward the underlying tissue they are more or less rounded, varying toward flat and angular outlines respectively, yet they are not facetted. (A simple columnar epithelium, as may be expected, consists simply of six-sided prisms, tending to be somewhat rounded above and below.) The tops of the basal cells may present four surfaces, three of which are sketched in Fig. 30, *B*. Thus, if it were possible to look down upon the cells of the basal layer and find one which was a perfect tetrakaidecahedron,

it would be oriented and appear like the central cell in Fig. 18. Because the overlying cells are larger than the basal cells, it often happens that the number of apical facets is less than four, and it seems in places as if a single cell might cover the entire top as in Fig. 30, *A*. But typically the apex should have two hexagonal and two quadrilateral facets; the six lateral surfaces, except as modified by the rounded base, should be two opposite quadrilaterals separated from each other, on either side, by a pair of hexagons. The volume of a basal cell is probably close to one one-millionth of a cubic millimeter, being thus one five-hundredth of the volume of a fat-cell, and one one-thousandth of the volume of an average cell of elder pith.

Although no mitotic figures were preserved in the sections studied, I have seen them in the similar epithelium of the oesophagus, so oriented that the basal cells were sometimes dividing vertically, and sometimes horizontally. Accordingly the new cells either push their neighbors apart, accounting for the sinuous lower margin of the epithelium, or they form a second layer toward the free surface. Cells in that layer enlarge considerably and cell division continues. Schwann appreciated the mechanical problem involved when he wrote,—"If the cells of the second stratum are twice as large as those of the first, then the whole layer must also be twice as large, were it not for the fact that the cells slide upon one another and a double or triple layer of cells may thus originate from one stratum of nuclei."

At the position indicated by asterisks in Fig. 19, a group of cells was found which could be followed quite satisfactorily, and five of them were modeled (Fig. 28, Pl. III). From left to right across the top and then down on the right, the total number of contacts of each of these cells is, respectively, 14, 15, 14, 14, and 12. Of their facets taken collectively, 3 are triangular, and 27 quadrilateral; 22 are pentagons; 9 hexagons, 6 heptagons, and 2 octogons. In this unpromising cluster one cell is found which on one side shows a nearly typical tetrakaidecahedral pattern (Fig. 29). It has fourteen surfaces, but the top and base, as oriented in the figure, are both pentagonal. In position in the epithelium these two surfaces are nearly vertical. On the left of Fig. 29, a single hexagonal surface extends from top to bottom. The cell which makes this contact presumably should have divided along the dotted line in the figure, cutting off a quadrilateral surface below and changing the pentagon on its right to a hexagon. The arrangement of the lateral facets in this epithelial cell duplicates exactly that in the lower of two elder cells shown in these Proceedings, Vol. 58, Pl. II, fig. 10.

The average volume of the five cells in this group is six times that of the basal cells, namely, .000006 c. mm. They are not closely applied to each other, but narrow intercellular crevices are bridged by many processes, outdoing in this respect the plant Sagittaria. At the corners there are decidedly larger spaces, again suggestive of the plant cells.

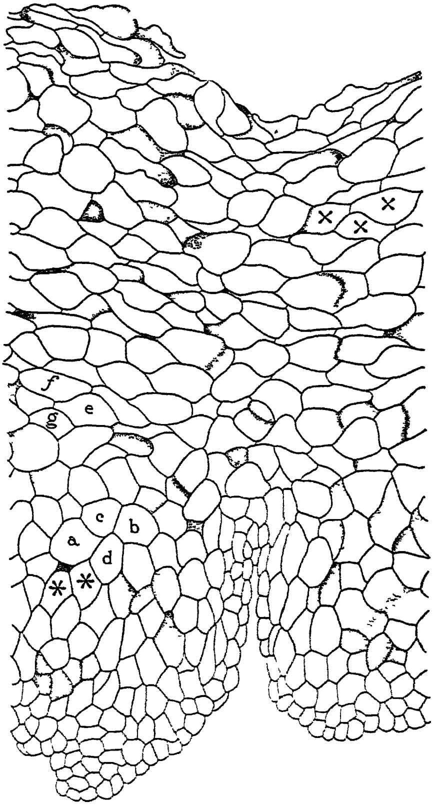

FIGURE 19. Vertical section of human oral epithelium. × 220 diam. Cells marked with * are included in the group modeled in Figure 28, Plate III; those with X, in Figure 27.

Near the free surface, the cells marked *X*, *X*, in Fig. 19 were found to be well sectioned for modeling and a group of four was reconstructed. The average volume of these four cells is .000018 c. mm.,—three times

greater than that of the preceding group. The cells are now shaped like pads or cushions, rather than like crystals; and the three most characteristic ones are shown in Fig. 27. The top cell in the drawing has 15 surfaces; the other two, 13 each. Two more cells at this level, one of which was not modeled, have respectively 15 and 13. Since the cells run out laterally into thin flanges, though the central part is large and bulbous, the counting of contacts is very difficult. The average number for these five is 13.8. Although still tetrakaidecahedral, these cells nowhere show the alternating squares and quadrilaterals; and they are far from possessing minimal surfaces, as seen in Table IV.

TABLE IV.

Epithelial Cell	Volume (cubic inches)	Surface (square inches)	Surface of orthic 14-hedron of same volume	Percentage which measured surface is of theoretical
1	2.35	27.5	9.40	292
2	3.05	29.6	11.17	265
3	3.57	27.5	12.42	221

Their surface area is between two and three times as great as it should be to account for the tetrakaidecahedral shape, and other factors must be in control. The outermost cells are somewhat flattened, without other changes, as if through some simple process of dessication.

The method by which this epithelium grows still defies geometrical analysis, so that such a section as shown in Fig. 19 illustrates Minot's remark in disparagement of mathematics:—"When we wish to understand a group of complex related details, such as an anatomical structure, we must see them, and if we can not see them no accurate conception of the group can be formed." The cells in the basal layers divide and enlarge actively, pushing each other apart, raising the resisting overlying mass to which they are bound, and finding some relief by the production of basal bulgings and the pockets which enclose papillae. At the level of the lower cells modeled, or shortly above it, they have acquired what is nearly if not quite their maximum vertical dimension, and the cells are then irregular tetrakaidecahedra, approximately isodiametric. Above that level the cells enlarge through imbibition or the less active methods of growth, increasing their volume (3 times in case of the cells modeled) and doubling their width. This seems to be accomplished by sending out lateral wedges, so that, for

example, cell *a* will join *b* (Fig. 19) lifting *c* from *d*. It has happened with cell *e*, which has gone out between *f* and *g*. Or, as Professor Davis expresses it, if cells 1, 2, 3, need more space, 2 is buckled upward in an arch, and 1 and 3 come together beneath it. On the extreme right of Fig. 28, one of these developing processes is strikingly exhibited, and the lateral ends of the cells in Fig. 27 show them in their final state.

From this it becomes clear that if an average outer cell has fourteen contacts, as our inadequate data indicate, all of them are not the same contacts which that cell had when in the lower layers. New ones are added as old ones are lost. There is a rearrangement of the cells, none of which is eliminated, though very rarely one is seen greatly compressed and shrunken. Believing that it should be possible to construct a geometrical figure of stratified epithelium fulfilling these conditions, many hours have been given to attempts which are still only partially successful. It can be shown that orthic tetrakaidecahedra may double their width and become flattened, still remaining tetrakaidecahedral through an equal gain and loss in surfaces, accompanied by a transformation of quadrilaterals into hexagons and *vice versa;* but only when a shearing is introduced which is not found in the actual epithelium, or if present, is disguised by a horizontal flattening of the outer layers. Comparing the diagrams with sections, it appears at once that the diagrams start from definitely oriented tetrakaidecahedra. Orientation in the lower layers of the epithelium (other than the basal layer) is as surely lacking as in adipose tissue; and the consequent irregularity of the cells may have advantages for producing the final pattern which no geometrically perfect form can offer. "Nature doth everywhere γεωμετρεῖν," Grew observed and Kieser quoted,—both in connection with erroneous descriptions of natural phenomena.

In the brief review of earlier work in my previous paper, no mention was made of Mirbel's studies of cell form, unwittingly following Kieser in his effort to discredit them. Finding vegetable anatomy "a backward science," Mirbel, in several publications, offered the brilliant suggestions and mistaken conclusions which were an easy mark for contemporary critics. In 1801, he pictured cells of the seaweed Laminaria as regular hexagons in cross section, and elongated hexagons when cut lengthwise, but quite too regular to please Rudolphi. In 1802, he ingeniously combined these sections in several large and clear schematic three-dimensional figures of parenchyma, which as Kieser

remarked, interest us at first glance; and in 1809, he published a tiny repetition of the same thing. About them all he had little to say other than that the shape results mathematically from the force of resistance meeting the force of external pressure (1801, p. 339). Kieser (1818) recognized that Mirbel was "unconsciously" picturing truncated rhombic dodecahedra, and wrote of his own work,—"Ich darf daher die folgende Untersuchung als ganz neu ansehen, und die Resultate derselben als eine neue Entdeckung über einen bisher ganz unbekannt gebliebenen Gegenstand."—which he illustrates by appropriating Mirbel's figure! Kieser was in fact the first to consider the mathematical aspects of the problem, declaring that minimal surfaces control the shape; that cells would be pentagonal dodecahedra if cells of that form could be fitted together in masses; and that in fact they were of necessity rhombic dodecahedra, "die Urform aller vegetabilischen und animalischen Zellen." This last conclusion the present studies have definitely overthrown. The irregularity of cells is such that it was never very warmly advocated. No alternative was offered until the physicists and mathematicians made known the properties of the tetrakaidecahedron, but that cells in aggregates were commonly tetrakaidecahedral was not then determined, or even predicted, by any biologist.

"Berthold and Errera, almost simultaneously, showed (the former in far the greater detail) that in a plant each new cell-partition follows the law of minimal surface"—but Thompson, who thus describes their important studies in his address "*Magnalia Naturae*," failed, as they had done, to draw the conclusion that cells are tetrakaidecahedral. Schaper, in a posthumous publication "Über die Zelle" (1906), edited by Roux, finds in the pentagonal dodecahedron "the prevailing cell-form," which conclusion Wetzel adopted (1922). Dr. Wetzel has informed me that he often discussed the problem with Schaper in Breslau, and that it was recognized that only through irregularities could these dodecahedra be associated in tissues. For Minot (1911) the irregularities are such that "we can not anticipate that there will ever be a mathematical expression . . . for even a single cell." Wilson (1925) who finds that "the form approximates to that of massed plastic spheres such as soap-bubbles or balls of clay," forgetting that these produce two radically different shapes, has in a measure adopted the conclusion of my previous paper, but he points out that "in the actual tissues these forms vary widely."

In place of these opinions it may now be said that such diverse types of cells as those of fat and of rushes, epidermal cells and parenchymal

cells of elder pith, are all primarily tetrakaidecahedral. Until it has been shown that any cells in other aggregates are of some different form, this becomes a general conclusion. The "irregularity of cells" is their deviation, in varying degree, from this particular pattern: too often it has been the expression of an imperfect comprehension of what the existing shapes actually are.

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EXPLANATION OF PLATES.

PLATE I.

FIGURE 20. Model of a group of stellate cells from the mature pith of *Juncus effusus*. $\times$ 400 diam.

FIGURE 21. Diagram interpreting Figure 20 on the basis of tetrakaidecahedral stars which have invariably lost their vertical processes, and occasionally others, as indicated.

PLATE II.

FIGURES 22–25. Models of four human fat-cells. $\times$ 400 diam. That shown in Figure 22 is extremely abnormal.

FIGURE 26. Model of a group of fat-cells (those indicated by asterisks in Figure 11). $\times$ 300 diam.

PLATE III.

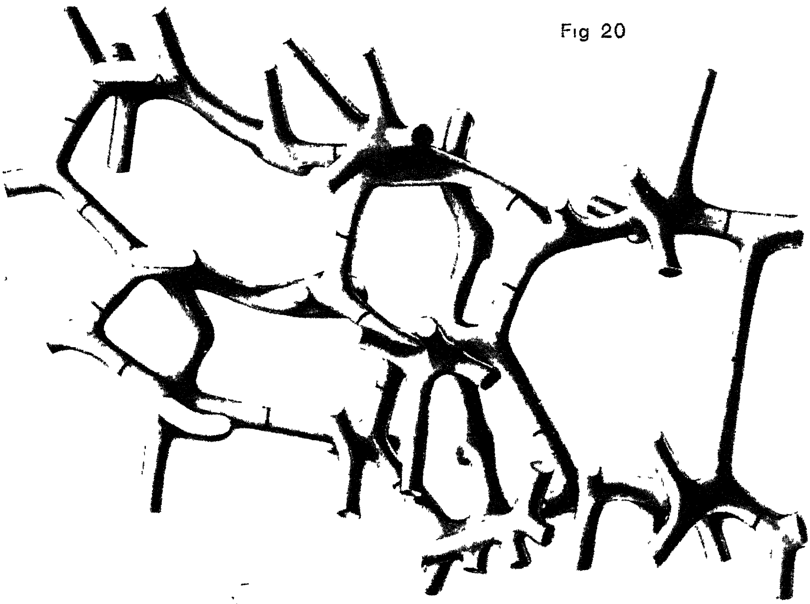
FIGURE 27. Model of three cells from the outer strata of human oral epithelium (from an embryo of about five months). The level of these cells is indicated by X,X, in Figure 19. $\times$ 1200 diam.

FIGURE 28. Model of a group of cells from the deeper layers of the same specimen (those indicated by asterisks in Figure 19). $\times$ 1200 diam.

FIGURE 29. Model, seen from another direction, of one of the cells included in Figure 28, which exhibits the tetrakaidecahedral pattern. $\times$ 1200 diam.

FIGURE 30. Sketch (not a reconstruction) of cells in the basal layer of this epithelium, at the same magnification.

Fig 20



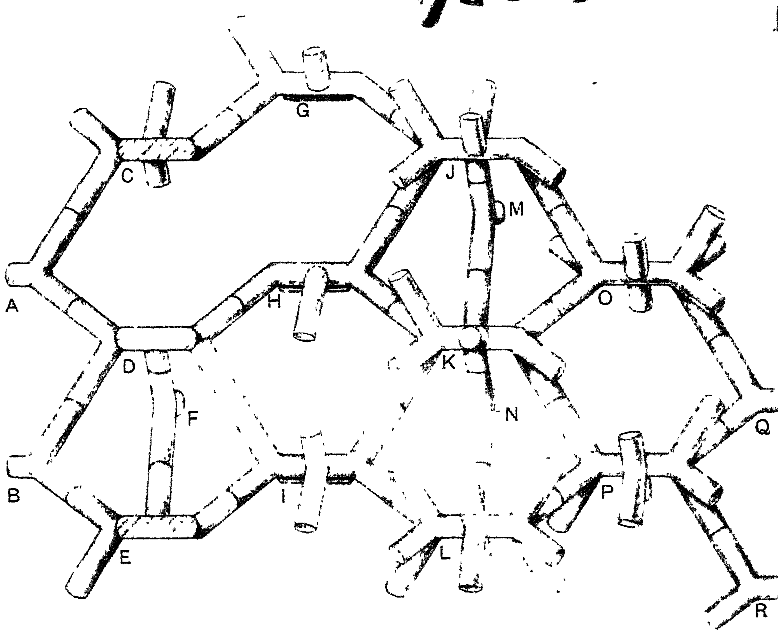


Fig 21

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Fig. 22

Fig. 23

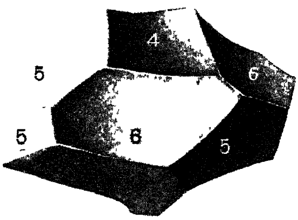

Fig. 24

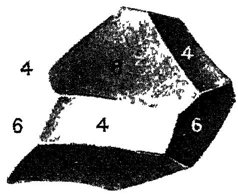

Fig. 25

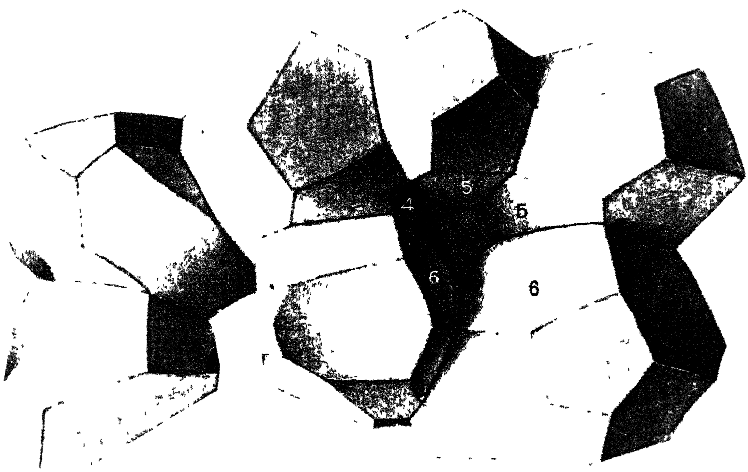

Fig 26

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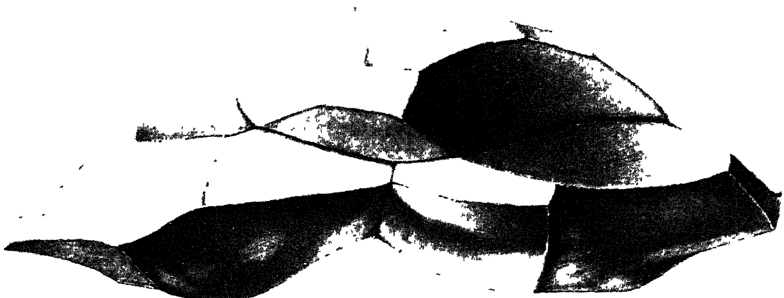


Fig. 27

Fig. 28

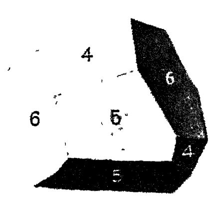
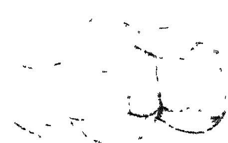


Fig. 29



A B C

Fig. 30

F. S. M. DEL.

Proceedings of the American Academy of Arts and Sciences.

Vol. 61. No. 2. December, 1925.

THE CALENDAR OF ANCIENT ISRAEL.

By W. A. Heidel.

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Received June 26, 1925. Presented November 11, 1925.

At present men generally pay little regard to the calendar, except as certain dates assume importance for their business. The historian, of course, is compelled to interest himself in it, because the past, with which he deals, divides itself into years and their parts; and the man of science, say the astronomer, requires it to specify the moment which his observations and calculations enable him to predict. These interests are felt to be secular, and we naturally tend to regard the calendar as a matter of practical convenience. Hence, proposals looking toward a simpler and practically automatic calendar are offered and entertained without regard to anything but their utility. By recent changes the western world has come to the almost universal use of the Gregorian calendar. The Jews, however, still retain the ancient reckoning for religious purposes—that is to say, in designating the holy days; and it is probably too much to hope that the adoption of the Gregorian calendar will result in the uniform observance of Easter among Christians.

In its origin the calendar is a religious institution, conceived for the purpose of fixing the times of the sacred festivals. "Times and seasons" were the *sacra par excellence* of the ancient Hebrews, as of the other peoples who were their neighbors; and these times and seasons certainly stood in a definite relation to the cultus. It is only reasonable to suppose, therefore, that the calendar of the ancient Israelites shared the vicissitudes of the people and their cultus, though the changes it underwent may have but partially reflected these experiences. Unfortunately the history of Israel is hard to trace in detail despite the comparatively abundant literary materials, being in fact obscured by the preponderantly religious interest of the writers. Not only was the Torah primarily a text containing directions for the cultus, to the practice of which it must of course be made to conform in essentials, but even in the ostensibly historical portions of the Bible, writers and revisers were much influenced by similar considerations. Even where the ancient texts were only slightly or not at all changed, later practice may have made itself felt in an altered interpretation, which the most enlightened historical criticism may fail to detect. Of such criticism the last half-century has yielded

much, which has sufficed to block out certain large masses of documents and to assign them approximately to given periods; but everywhere there remain portions, usually of the utmost importance for detailed history, which, though recognized as redactorial, cannot be accurately referred or dated. Where scholars of acknowledged competence have failed to reach a satisfactory agreement, one who, like the writer, does not pretend to be a master in this exacting art of criticism, will perforce tread warily.

By far the most penetrating study of the history of the calendar among the Hebrews in the period before the Christian era we owe to Dr. Julian Morgenstern.[1] Though the writer has been engaged upon the same subject for a decade, he hesitates to take issue with a scholar who is at once so competent to deal with all the sources and so well informed, especially as the results of the two concurrent inquiries are in certain essentials substantially in agreement. The present discussion will, therefore, avoid polemics and confine itself to a statement of the author's findings; and it will not take up all the questions connected with the calendar, because many of these cannot be intelligently considered without entering at length and in great detail into the history of the pilgrimage festivals and the other holy days of Israel.[2]

Dr. Morgenstern speaks of the three calendars of ancient Israel. The writer also had reached practically the same result, though he preferred to speak rather of three phases of the calendar, for reasons which will presently become clear. We shall be concerned chiefly with the nature of the calendar in its several phases and with the influences which shaped and affected it.

We have already referred to the obscurity that involves much of Israel's history. This is due to the character and fortunes of our sources, which the means at the disposal of the historian do not suffice to disentangle, because of the relative paucity of independent data furnished by records free from the suspicion of later interested revision. Even in post-exilic times much which passes for history must be pronounced dubious; and in the earlier periods comparatively little can be seen in a perfectly clear light. In this situation the historian will seek first of all such data, however few, as may be set down with reasonable certainty; and then only will he be free to attempt a

[1] "The Three Calendars of Ancient Israel," in *The Hebrew Union College Annual*, vol. 1 (1924), pp. 13–78.

[2] The writer has such a work in preparation and was led to study the history of the calendar because of the problems that arose in connection with the dating of the festivals.

reconstruction, using such other data as can with certainty or probability be combined with those upon which his structure rests.

As such a datum, at once fundamental and reasonably assured, we regard Josiah's reformation in 621 B.C., and hold that "the book of the law" found in the house of Yahweh, which prompted his reform-measures, was one containing the core at least of *Deuteronomy*.[3] Now one of the most important steps taken by the king was the attempt to achieve the concentration of the cultus at Jerusalem, as was enjoined by the book of the law. Of the conditions which preceded this reform we know very little; but it may be safely assumed that the other local shrines, some of which tradition represented as not only of great antiquity but also as held in exceptional veneration, had hitherto clung to their primitive usages, such as their pilgrimage-festivals, which, as we learn from the Talmud, continued for centuries thereafter to be celebrated as rural observances outside Jerusalem. In view of the abundant evidences of the virtual independence of these shrines it would be surprising if they did not have different calendars, as in Greece, where particularism was no less pronounced, neighboring petty states are known to have preserved distinct calendars down to a much later date. But whatever their differences, we may well assume that they were fundamentally quite similar, as were the calendars of the Greek states. With the attempted centralization of the cultus at a single sanctuary came quite naturally a demand for a single sacral calendar. If one was then introduced, we should expect to find that it acquired a special sanctity as being inseparably connected with the new order of the cultus, which was accepted as expressly ordained by Yahweh; and as the reform was conceived as a restoration of a practice originally enjoined by Moses at the command of the God of Israel, it was not only permissible but clearly right to correct the older Torah in accordance with it.

Now there is clear evidence of a change in the calendar at a date not long subsequent to the reform of Josiah. We do not know just when it was made; but it seems reasonable to assume that this measure was adopted by the priesthood as one calculated to give practical effect to the ideal of a united Church, rather than proposed in "the book of the law," which naturally assumed the form of a manifesto of the reform party. The need of taking this step may well have

[3] The Deuteronomic reformation has lately been called in question, but the arguments adduced by the newer critics in support of their contention appear to the writer inconclusive and negligible. If the results of this study of the calendar of Israel are accepted, they give indirect but important confirmation to the view generally held by scholars.

been realized only after the newly constituted Church seriously faced the problems of its organization in detail. It is from *Ezekiel* that we learn of the existence of this calendar; for the prophet[4] dates his vision of the temple on New Year's Day (Rosh ha-Shanah), the 10th day of the month. To one who is acquainted with the ancient calendars of the Eastern Mediterranean Basin this is an interesting datum, the significance of which has hardly been understood.

Most ancient calendars known to us are lunar, the year being composed of months which coincide more or less accurately with the lunations and begin with the new moons. The year, ordinarily consisting of twelve months, occasionally adds a thirteenth in order to make good the deficiency relative to the seasons. There are, of course, a few calendars which disregard the lunations and concern themselves primarily with the solar year, using months of conventional length. Now as regards the datum of *Ezekiel*, it is obvious that it implies an equation between two calendars; for "the 10th day of the month" is certainly said with reference to a reckoning other than that which made it New Year's Day. Our problem is to discover the character of the calendars which are thus brought into relation to one another. One thinks of several possibilities, which must be canvassed. It requires little reflection, however, to rule out the possibility of both calendars being lunar, because on that supposition the year, whose beginning must coincide with that of a month, could not date from the 10th day. Some scholars have suggested that the datum of *Ezekiel* is to be explained by the anomaly, twelve lunations (354 days) falling short of the solar year; but if we take this as 365 days, on this view New Year's Day must fall on the 12th, not the 10th, day of the month.[5] There must be considered also the possibility that both calendars here brought into comparison were based on the solar year. This hypothesis has something in its favor, because it would make the relation of the two calendars constant, so that the one might always be nine days in advance of the other; and this would give a satisfactory explanation of the fact, to which we shall presently recur, that the coincidence of New Year's Day with the 10th day of

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[4] 40, 1.

[5] It has been suggested, likewise, that the earliest Israelite calendar, like that of the *Book of Jubilees*, reckoned 354 days to the year. There is nothing to support this hypothesis, which is in itself improbable. The desire to make the year contain an even number of weeks ($364 = 52 \times 7$), accounts for this arbitrary number; but there is no evidence for the cyclical week before the second century B. C. Moreover, on the assumption of such a year, New Year's Day would be the 11th following the twelfth lunation.

the month is clearly assumed in other relations which seem to have no obvious connection with the time of *Ezekiel*. Without wishing in the least to minimize this point, which must be conceded to have considerable weight, we seem to be compelled, however, to reject the hypothesis that both calendars referred to by *Ezekiel* were solar; for, quite apart from the improbability *à priori* of meeting two such calendars among the Jews, when but very few are found anywhere at that date, it must be clear that one of the two calendars brought into comparison was either the current Babylonian or the pre-exilic Israelite calendar, both of which were lunar. We have come to know a good deal about the Babylonian at different periods, and every indication shows that it was lunar, the anomaly being adjusted first by occasional, later by periodic, intercalation of a lunar month; and we shall presently see that all the evidence regarding the ancient calendar of Israel requires us to regard it also as lunar. There remains, therefore, no alternative but to hold the other calendar to be solar: this is, of course, the one whose New Year's Day is dated on the 10th day of the (lunar) month.

It will be recognized that the datum of *Ezekiel* is, when thus considered, of exceptional interest; but its significance appears only when one follows the clew which the prophet's statement affords. The cardinal fact is, of course, that we discover a calendar based on the solar year and dating from the 10th day of the (first) lunar month; and this calendar is presumably sacral, because *Ezekiel* dates his vision of the restored temple on its New Year's Day. The Torah,[6] as it chances, contains other data of an analogous character, which are likewise brought into relation with New Year's Day; but they are quite certainly of later date and refer to a different calendar. It becomes a matter of the first importance, therefore, to distinguish the strata which may thus be traced. Our immediate concern is with the epoch disclosed by *Ezekiel*, which is known to underly at

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[6] *E. g.* *Exod.* 40, 2 and 17. For similar associations of New Year's Day among the Babylonians see Morgenstern, "The Three Calendars of Ancient Israel," pp. 48 sq. and King, *Legends of Babylon and Egypt in Relation to Hebrew Tradition*, p. 72 sq. Egyptian records suggest a similar connection between the New Year and the dedication or rededication of temples. The 25th Kislev, as the date of Hanukkah or the Feast of Dedication, suggests—what is highly probable on other grounds—that the day was New Year's Day in some calendar, presumably as the *natalis solis* (= 25th Dec.). When the *Mishnah* says that the Day of Atonement was the anniversary of the consecration of Solomon's temple we are justified in regarding the statement less as a historical datum than as evidence that the 10th day of Tishri was still recognized as New Year's Day.

least one other arrangement; for, according to *Lev.* 25, 9 sq., the Jubilee Year was to be heralded with the blowing of trumpets on the 10th day of the 7th month. One cannot doubt that this was to be New Year's Day. Moreover, the same date is given for the Day of Atonement,[7] which must from the beginning have been recognized as a New Year's observance.[8] Even in the Talmud there is the clearest evidence of it being so considered, as indeed a comparison of the rites belonging to the day with those of the Babylonian and other New Year festivals makes abundantly evident. The 10th day of the month is thus a New Year's Day in two distinct relations, there being no reason to assume an original connection between the Day of Atonement and the inauguration of the Jubilee Year. We shall presently find grounds for the belief that Sukkot also was dated from the same epoch: if that be true, we have discovered a third relation in which the 10th day of the 7th month figures as New Year's Day. The Israelites, however, like most other peoples of Western Asia, observed another epoch in the spring. The vernal festival of the Hebrews is of course Passover, which the entire biblical tradition regards as a New Year's observance. It is important for our purpose, therefore, to note the data of the Torah regarding Passover. This festival is inseparably connected with the exodus, which it was thought to commemorate. The departure from Egypt, it was thought, began on the night of Passover, and this event was not obscurely dated at the turn of the year[9]: "Now the time that the children of Israel dwelt in Egypt was four hundred and thirty years. And it came to pass at the end of four hundred and thirty years, even the selfsame day it came to pass, that all the hosts of Yahweh went out from the land of Egypt. It is a night of watching (*i.e.* a watchnight, or vigil) unto Yahweh." One requires neither special acumen nor familiarity with observances held at the turn of the year to recognize in these statements a reference to the New Year. Now it is a matter of common knowledge that the Torah appoints the 14th–15th of the 1st month as the *mo'ed* of Passover; but it likewise ordains[10] that the paschal victim shall be chosen on the 10th day of that month, which thus becomes the pre-festal day (*proëortia*) of Passover, marking the initial step of the ceremony. If we hold, as we must, that Passover is a New Year festival, it is

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[7] *Lev.* 16, 29.

[8] Cp. *Ezek.* 45, 18–20. Here (45, 20) we must read with LXX "and so thou shalt do in the seventh month on the first day of the month."

[9] *Exod.* 12, 40–42.

[10] *Exod.* 12, 3.

clear that it dates from the 10th day of the 1st month, which thus becomes the vernal epoch, corresponding absolutely to the autumnal epoch on the 10th day of the 7th month. We have not, however, exhausted the biblical evidence regarding this New Year's Day. The exodus begins with Passover, but it likewise ends with Passover: after forty years Israel enters Canaan by passing over Jordan, and we are told[11] that "the people came up out of Jordan on the 10th day of the 1st month, and encamped at Gilgal," where they presently celebrated Passover on the 14th–15th, and thereafter first ate of the produce of the land.[12] Thus the exodus is framed at both ends by Passovers marking the turn of the year and embodying the same time-scheme. There are those who regard Sukkot as the original New Year's festival of the Israelites: whether or not that be true, from the earliest to the latest reference to it one clearly sees that it was always regarded as marking the turn of the year. When, therefore, one notes that in the Torah its *mo'ed*, dated on the 15th day of the 7th month, follows the autumnal epoch at the same interval that separates Passover from the vernal, one cannot doubt that this observance also was dated from the 10th of the month. If we add that the Torah brought Pentecost also into a definite relation with Passover, it is seen that the three times of required pilgrimage, as well as the Day of Atonement, are definitely referred to this calendar. This being established, there can be no doubt that this is the sacral calendar of Israel *par excellence*, and that it was regarded as having a peculiar sanctity.

About the time when this calendar must have been introduced there appears in the biblical texts,—probably first in *Jeremiah*,—a new manner of referring to the months by number rather than by name, which continued in vogue until quite late times.[13] This custom, for which neither the Phoenicians nor the Babylonians[14] offer a parallel, can hardly be explained except on the assumption of a rather violent break with the past, when, as we know, the Hebrews used the names for the months current among the Canaanites; and the change must

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[11] *Josh.* 4, 19.

[12] *Josh.* 5, 10 sq.

[13] See Morgenstern, "The Three Calendars of Ancient Israel," pp. 16 sq.

[14] One may add the Assyrians. See H. Ehelolf and B. Landsberger, "Der altassyrische Kalender," in *Zeitschr. d. Deutsch. Morgenl. Ges.*, vol. 74, pp. 216–219. The months were designated by name, not by number. Twelve names only have thus far been discovered and their order determined. Though no intercalary month is yet known, these Assyriologists expressly caution us against drawing hasty conclusions from that fact. It is altogether probable, though not yet certain, that the Assyrian calendar was not solar, but lunisolar.

have affected the months, which can no longer have coincided with those by which one formerly reckoned. This is just what we should expect to find, if our hypothesis be true, that there was a new calender based on the solar year. The mere fact of the months being numbered suggests also that their number was constant, as it could be only on that hypothesis, since a lunar calendar must frequently reckon an additional month. Furthermore the Torah pays noticeably little regard to the phases of the moon; new moon, of which the early prophets had much to say, is almost ignored[15]; and though in the time just preceding the Christian era Jewish writers emphasize the fact that Passover and Sukkot fell at full moon, as from their dates they must in a lunar month, it is noteworthy that this in itself sufficiently striking phase of the moon goes entirely unmentioned in the Bible, except in two passages[16] which are obviously quite late. This fact, hitherto little regarded, certainly suggests that the major festivals were not timed with reference to the full moon, and is intelligible if the coincidence was unintentional, as it would be on the assumption that the calendar by which the dates were fixed had no relation to the lunations. There is, moreover, another singularity in the biblical texts, which has hitherto remained unexplained, and owing to the complexity of the literary tradition is likely to continue to cause difficulty. The word *hodesh*, which in Phoenician always means "new moon," somehow came in Hebrew to have in addition the meaning "month." This development is in a measure intelligible; but when one notes an apparent tendency to avoid the use of *hodesh* in the sense of "new moon" and to substitute for it the phrase "the first day of the month," it gives one pause. It seems unlikely that this locution should have arisen except under the influence of a calendar which disregarded the lunation and employed a conventional month. The biblical text, therefore, may confidently be said to compel us to postulate a calendar based on a solar year having twelve months of arbitrary length.

It is well known, however, that this calendar was not in use among the Jews in the centuries last preceding the Christian era; but the *Book of Jubilees*, which denounces the observation of the moon practised by contemporary Jews, sets forth a solar calendar yielding a year

[15] The only important exception in P. is *Num.* 29, 6, where the reference to the new moon has the appearance of an addition. In any case the passage is late. In *Num.* 9, 1 and 20, 1 one suspects that *hodesh* was originally used in the sense of "new moon" rather than of "month."

[16] *Ps.* 81, 3, *Prov.* 7, 20.

of invariable length,[17] which it says was written on the heavenly tablets and communicated to Moses by an angel. Whatever else one may conclude from this fact, one may safely infer that a calendar based on the solar year and disregarding the lunations was known to Jewish tradition as Mosaic, and therefore somehow contained in the Torah. A study of the *Book of Jubilees* shows that in essentials the data which it purports to derive from the heavenly tablets agree with the solar calendar we have been considering.

It will naturally be asked, under what influences this calendar was adopted. If its character was such as our analysis leads us to infer, it is clear that we have no reason to look to either Canaan or Babylon for the original on which it was modelled; for there, according to all that we know or may reasonably infer, lunar calendars were used and months were distinguished by name instead of number. It is true that the Babylonians did in business transactions reckon a month as of 30, a year as of 360 days,[18] as bankers even now are wont to do; but their religious festivals, even New Year's Day, were dated by the lunar months. In Israel, however, it is chiefly the festivals hallowed by immemorial observance that were brought into relation with this solar year. We shall presently find evidence that these very observances were redated after the composition of *Deuteronomy* and before the time of *Ezekiel*. At that time there is little likelihood of the Israelites framing such a calendar except under the influence of an advanced civilization; and if we cast about for a people that might have exerted that influence we think inevitably of the Egyptians. In Egypt we find in fact for many centuries before that time a calendar in use, which was based on the solar year and employed conventional months of 30 days without regard to the lunations. The months also were numbered,[19]—not continuously, to be sure, but within the limits of the seasons, of which there were three. These seasons—of sowing, of growing, of harvest and inundation—did not correspond to the natural divisions of the year in Palestine; hence, if that calendar was to be adopted, it was natural that the seasons should be ignored and the months numbered consecutively throughout the year. That it was in fact the Egyptian calendar that furnished the model for the Church Year of the Jews seems to be confirmed by the calendary arrangements for its New Year festivals. The Egyptian year con-

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[17] The year consists of 12 months of 30 days, *plus* 4 memorial days, making 364. The Talmud also knows a year of that number of days.

[18] See Kugler, *Sternkunde und Sterndienst in Babel*, 2, 192.

[19] The months are named in documents only of late date.

sisted of 12 months of 30 days *plus* the 5 *epagomenae*, the latter occupying an ambiguous position apart and being regarded in the older time as a prefix, in the latest period as a suffix, to the year proper. Thus, since the year proper counted but 360 days, either the 361st or the 366th might with almost equal propriety be regarded as New Year's Day. But this interval of five days, which in Egypt constituted a special season of religious observances as the nativities of the five Osiride gods, is precisely that which intervenes between the New Year's Day of *Ezekiel* and the *mo'ed* of either Passover or Sukkot, which, as we have seen, were ancient New Year festivals. This relation is brought out with all possible clearness in connection with Passover; for there the selection of the paschal victim on the 10th, and the distinction between Pesah, referred to the 14th and characterized as a watchnight or vigil, and Mazzot, referred to the 15th, afford a precise and complete parallel to the Egyptian scheme, since in Egypt not uncommonly festivals begun in one month ended on the first day of the following one, and in particular New Year's Day was preceded by a preliminary rite on New Year's Eve.[20] Since Passover fell in the "first month," it was the New Year festival *par excellence*;[21] Sukkot, as one sees from *Ezekiel*,[22] was merely another Passover, introducing the second half-year. Theoretically the Egyptian year likewise began in the spring, though by disregarding the fractional excess of ¼ day the calendar actually fell behind the seasons.

If, then, the calendar underlying the Jewish Church Year was adopted under Egyptian influence, one asks whether it is possible to date it. It is conceivable that the datum of *Ezekiel*, which is confirmed by the festival calendar, that New Year's Day fell on the 10th day of the (lunar) month, might enable one versed alike in Egyptology and astronomy to approximate the date within narrow limits, because the New Year in question is undoubtedly the vernal epoch, which was presumably reckoned from either the vernal equinox or the heliacal rising of Sirius (Sothis). If the attempt is to be made, however, let it be done by one who is competent. We shall do well to limit our inquiry to considerations of a more general character, which, though incapable of yielding a definite date, may suffice to indicate a period covering no great number of years. Already we know the outer

[20] See Erman, *Aegypt. Religion*,[2] p. 211.
[21] Cp. Georgius Syncellus, 126 C: "In the 3816th year of the world, when Moses had completed his 80th and begun his 81st year, on the first day of Unleavened Bread, the 14th day of the lunation, at midnight, The Lord commanded that all the first born in the land of Egypt be slain."
[22] 45. 25.

limits; for the change of calendars must lie between the date of *Deuteronomy,* which is presumably not much earlier than 621 B.C., and *Ezekiel,* who refers to the 25th year of the captivity. But one may surely narrow the time even more; for, if the calendar was adopted in this period, it must be connected with the reformation of Josiah, which began in 621, and if it was shaped by Egyptian influence, it cannot well date after 605, when the dominion and influence of the Egyptians in Palestine were rudely broken by the crushing defeat they suffered at the hands of the Babylonians in the battle of Carchemish. In all probability, however, the calendar was not the first measure of the reform movement, but came into being when the priesthood found leisure for the work of regulating the cultus in detail; and this, we may assume, occurred toward the end of the period in question. Thus one may with some confidence date the introduction of this solar calendar between 610 and 605 B.C.

A few years ago this finding would have been pronounced impossible, because irreconcilable with history. When the writer reached the conclusions above set forth, he was much troubled by them, because he could neither deny their cogency nor fit them into the scheme of history as he knew it. It was then generally accepted as certain that after the failure of Psammetichus to complete the capture of Ashdod, the siege of which he was forced to abandon by the incursion of the Scythians, until the fall of Nineveh in 607, the Egyptians had played no active part in the affairs of Syria and Palestine. They were supposed to have been on the side of Babylon in the struggle which resulted in the destruction of the Assyrian Empire, the old enemy of Egypt, and to have attempted to appropriate the western dependencies of Assyria as their share of the spoils of victory, which Babylon begrudged them. Their dream of a renewed Asiatic empire was dashed at Carchemish two years later. Under these circumstances it required an almost heroic faith in the results of a critical analysis to maintain the thesis of a strong cultural influence of Egypt in Palestine at a time when it seemed impossible to account for it. But a recent discovery has gone far to vindicate that faith by showing that the political relations existing at that time were such as to favor, instead of precluding, a strong Egyptian influence in Palestine. The new fragment of a Babylonian chronicle published by Mr. Gadd[23]

[23] *The Fall of Nineveh. The Newly Discovered Babylonian Chronicle, No. 21,901, in the British Museum. Edited with Transliteration, Translation, Notes, etc. by C. J. Gadd, M.A., Assistant in the Department of Egyptian and Assyrian Antiquities, British Museum, with a Photographic Reproduction and Six Plates. Printed by order of the Trustees, 1923.*

has completely changed our views of the events connected with the collapse of the Assyrian Empire. It now appears probable that after the Scythians, about 630 B.C., made their raid through Western Asia, advancing to the very frontiers of Egypt and then retiring, Psammetichus, king of Egypt, fearing a new invasion from the same quarter, and regarding Assyria as his first line of defense, made common cause with his old foes, the Assyrians, and as the latter, under great pressure from the Scythians, the Medes, and the Babylonians, withdrew their forces from Syria and Palestine for the defense of the homeland, moved northward and with his forces occupied that region. At all events the newly discovered chronicle reveals the fact that an Egyptian army, which can hardly have come directly from Egypt for this purpose, engaged in joint operations with the Assyrians against the forces of Nabopolassar of Babylon along the Tigris in the autumn of 616, and again in 609 vainly attempted, in conjunction with the remnant of the Assyrian army, to recover Harran, which had been taken by the Scythians and Babylonians. In view of this situation it now appears more than ever doubtful whether there ever was a battle fought at Megiddo, in which, according to *2 Chron.* 35, 20 sq., King Josiah was slain. The view long held by some scholars, based on the account of the affair in *2 Kings* 23, 29 sq., now gains appreciably in probability, to wit, that Josiah coming to Megiddo in response to a summons from King Necho of Egypt, was set upon and slain by the royal guards. The motive may well have been to remove one who, owing to his power and position, might prove dangerous, if he should threaten the line of communication with Egypt, while the army was engaged in operations far from home. In any case, Egypt must have been in control of Palestine for a considerable period, even before the fall of Nineveh, which we now know occurred, not in 607 but in 612; and of course continued in possession until defeated by the Babylonians at Carchemish in 605. Thus during the very period in which we must date the calendar of the Jewish Church Year, which seems to show Egyptian influence, Egyptian influence must have been paramount in Palestine.

But, as we have seen, the influence of Egypt in Palestine, though naturally great at the crucial moment of the reformation of Josiah, in which the Jewish Church was born, was destined to be short-lived. Hardly had the new order been established, when unspeakable disaster befell the state which the king of Judah was trying to renew and strengthen by a revival of religion conceived as a return to the faith of the fathers. Perhaps the sympathy with Egypt was the stronger

in Palestine because a similar reform was just at that time being undertaken by Psammetichus in the land of the Nile. The massacre of Josiah and the dethronement of his successor, followed by the accession of Jehoiakim under the protectorate of Necho, weakened the State without apparently affecting the Church, which suffered a great shock, however, by the fall of Jerusalem and the Babylonian captivity. In consequence of these events, which followed one another in rapid succession, the Jews found themselves in greatly altered circumstances. Babylon had taken the place of Egypt, and among the leaders of the people in particular, who were deported, the influence of Babylonian institutions must have been strongly felt. There seems to be no reason to doubt that during the captivity, both in the homeland and in Babylonia, the Jews in ordinary affairs used a calendar which in essentials agreed with the Babylonian, though they might continue certain practices, such as that of designating the months by number, begun in the time of Josiah or of his immediate successors. We meet the Babylonian names of the months only in very late documents. This change was the more natural because the earlier calendar of Israel, as we shall presently see, was, like the Babylonian, based on a lunisolar year. In affairs of the Church, however, the calendar of the reformation had acquired a status which for a time protected it. We find its New Year epoch in the Code of Holiness and in other documents of the Priestly Code, some of which appear to date perhaps as late as the Persian or even the Hellenistic periods. This fact is at first sight disconcerting, because under the circumstances New Year's Day, even in a calendar based on a solar year, cannot have regularly fallen on the 10th day of the month. We must, therefore, assume, as the only possible explanation, that this equation of dates was conventional, having been adopted when the Church Year was instituted and afterwards retained by custom until in the end its very existence was forgotten.

The brevity of the period during which the calendar of the reformation remained in common use created a situation which calls for further remark. One result was that when a lunisolar calendar speedily succeeded the solar in practical affairs a certain amount of confusion must have ensued, because there would inevitably be two New Year epochs. This fact is the more important because throughout Western Asia the chief festivals were essentially calendary, being in large part concerned with the transition from year to year and so, in a word, New Year festivals. Moreover, the rites practised on these occasions among the several peoples had very much in common: so much, in

fact, that it is difficult to see how the analogy or even the essential identity could fail to be discerned by one who was placed in a foreign environment. The Jews who were transported to Babylonia must have felt that the New Year's observances which they witnessed there were akin to their own, though they fell at a different time. So far as we can judge from the record the Church Year of the reformation took cognizance of Passover and Sukkot alone, though it is probable that Pentecost was dated with reference to the former. Whether the provision for the Jubilee Year was included in the original scheme is not certain; but it dates from the autumnal epoch of the reformation-calendar and is clearly the analogue of Pentecost. At all events, the exile must have nullified the ordinance, if it was adopted, and we have no evidence of the observance before the second century B.C. The Day of Atonement owes its ritual development to a later time; but its distinctive features were in keeping with observances of earlier date, which undoubtedly were performed on New Year's Day. When these were adopted by the Church and acquired their representative character, the ecclesiastical New Year's Day was naturally chosen: the priesthood obviously still retained a memory of the fundamental Church order. Meanwhile, however, other observances had grown up, or in some instances perhaps had survived the reformation, which, as being connected with the lunisolar calendar in common use, were regarded as secular or at best as of secondary importance to the Church. In process of time, however, they won ecclesiastical recognition and were admitted to the festival calendar of the Church. Chief among these was the secular New Year's Day, celebrated on the 1st of the 7th month; but the new moons also recovered their old-time honors.[24] Rosh ha-Shanah came to be regarded as a preliminary or premonitory Day of Judgment, announcing the approach of the Great Doom's Day, the Day of Atonement, which marked at once the end of one cycle ('Olam) and the beginning of another. It is only in the Talmud that we find the significance of this day fully appreciated; but the parallels furnished by Babylonia and Persia warrant us in assuming that the spiritual associations of this typical New Year's Day were not acquired at so late a date. In Talmudic times Rosh ha-Shanah was thought to be the epoch of the Jubilee

[24] It is hardly credible that the new moon, observed with special rites from time immemorial, was ever in Israel neglected, see *Ezek.* 45, 17; 46, 1–6. But as the holy days of Israel always had, or tended to have, a definite relation to the calendar, the new moon also reclaimed its calendary connection in late Judaism: it is against such observation of the new moon that Moses is urgently warned in the *Book of Jubilees.*

Year, and a secondary New Year's Day was observed on the 1st of Nisan. Thus, though the steps of the change cannot be dated in detail, the drift from the calendar of the reformation to that of later times is clear.

In the last centuries preceding the Christian era other festivals, such as Hanukkah and Purim, found acceptance. Their relation to the calendar of Israel is obscure, if indeed they may be said to have had one, because they are probably of foreign origin, introduced by Jews of the Dispersion. Certain data also contained in *Chronicles*, *Ezra* and *Nehemiah* suggest confusion and uncertainty in regard to the proper dating of festivals, by which we are prepared for an understanding of the striking fact that the rabbins of the Talmud had lost touch with the order that underlay the Church Year of the reformation. The fiction of the Mosaic origin of the ordinances instituted at the reformation tended to obscure the historical relation and led to the revision of the older documents in matters of prime importance to the cultus, except where a harmonistic interpretation seemed to meet the requirements of the Church.

After thus sketching the vicissitudes of the calendar from the reformation of Josiah to the beginning of the Christian era, let us turn our attention to the earlier period. As has already been confessed, there is much even of major importance which we know imperfectly or not at all in regard to the history of Israel at that time. In reference to the calendar, which now engages our thought, we are reduced to the necessity of arguing from analogy and drawing inferences from data which are few in number. The evidence, however, though far from abundant, is fortunately so concordant and of such character as to admit of but one conclusion regarding the nature of the calendar or calendars in use. It was suggested above that before the centralization of the cultus of Yahweh at Jerusalem the various local shrines, at which the Israelites had worshipped from time immemorial, may have had their own reckoning, as was the case in Greece and to a certain extent in Babylonia. Though we can adduce no proof that this condition obtained, there is a certain antecedent probability in favor of the assumption. This would be possible even if, as we assume, the calendars in use were of the same sort. We shall presently produce the data from which we infer that the early Israelites had a lunisolar year. Now in such reckoning much depends on the practice of intercalation; and every student of the calendars of ancient nations is aware of the difficulties they experienced in this respect. The lunar year is continually falling behind the seasons:

when the discrepancy became intolerable, if the calendary rites were bound to the natural seasons, it would be in a measure corrected by the insertion of an intercalary month, but this remedy need not be simultaneously applied by the priests in their several sanctuaries. Even in Babylonia there appears to be no evidence of a fixed period of intercalation before the sixth century B.C., and in Greece, likewise, definite cycles seem to have originated about the same time. It is, therefore, not improbable that the Israelites proceeded in a similar empirical way; but in general a people whose festivals were, like those of the Canaanites, in good part concerned with agriculture, would rarely allow their years to fall much more than a month behind the seasons.[25] Thus neighboring sanctuaries might easily differ at times by a month in their reckoning. It is possible, indeed, that there is an actual instance of this sort in the report[26] of the festival which Jeroboam instituted in Bethel and Dan, although the text, which dates from the exile long after the event and clearly reflects the calendar of the reformation, suggests other reasons for holding the festival in a different month from that in Judah. The historian writes from the point of view of Judah, and refers to the months by number, whereas in the time of Jeroboam, we may be sure, they were designated by the ancient Canaanite names. It is altogether probable that both festivals were connected with the autumnal New Year, but owing to the difference in intercalation one was dated in Bul, the other in Ethanim, which the historian translates into the terminology of his day as the 8th and the 7th months.

Of the names of the months anciently in use among the Israelites the Bible preserves but four: to wit, Abib, Ziv, Ethanim and Bul. With the exception of Abib they are found in Phoenician inscriptions: we may be sure, therefore, that they were taken over from the Canaanites. These names, occurring in the older biblical documents, continued in use until just before the exile: where they are found in books dating from the exile they are interpreted in terms of the calendar of the reformation and obviously reflect the usage of an earlier date. *Deuteronomy*, in a passage which may confidently be assigned to "the book of the law" found in the house of Yahweh in the eighteenth year of Josiah, mentions the month of Abib in a way that

[25] In the course of history the order of the months in the Babylonian calendar was shifted, presumably for this very reason. Ehelolf and Landsberger, *l.c.* p. 218, note a similar shift in the Assyrian calendar in comparison with the Babylonian. In Greece also there is evidence, which we may point out on another occasion, of the same sort of change.

[26] *1 Kings*, 12, 28 sq.

requires us to regard the name as still in current use. Thus the most ancient manner of dating, of which we have evidence among the Israelites, appears to have continued in use almost, if not quite, down to the time of the reformation. In view of this fact and the evidence, already adduced, of a new manner of dating, which occurs in documents, such as *Jeremiah* and *Ezekiel*, belonging to the time just preceding the exile or shortly after its beginning, we do not hesitate to connect the new calendar, which thereafter fixed the dates of the major festivals, with the reformation itself, which created Judaism. But the complete change in the manner of dating which then began can hardly be understood except on the assumption that the new calendar differed radically from the old.

The new calendar, as we have pointed out, was obviously based on the solar year: we should, therefore, be predisposed to expect that the evidence available for defining the character of its predecessor would point to a lunisolar year. And so in fact it does. As we have seen, the texts which are most closely connected with the reform of Josiah ignore the new moons, for which the older documents evince a high regard. There the new moons are coupled with the sabbaths and *mo'adim*[27] in such sort as to leave no doubt regarding their connection with the cultus as practised at the local shrines. Moreover, the stories of Elisha and the Shunammite[28] and of David's pretended departure for Bethlehem,[29] when he incurred the enmity of Saul, show that the new moon was the customary time of meeting at the sanctuaries. The latter incident especially is important, because David is represented as saying to Jonathan, "If thy father miss me at all, then say, David earnestly asked leave of me that he might run to Bethlehem his city; for it is the yearly sacrifice there for all the family." From the context we learn that the morrow, when David should be at Bethlehem, was to be new moon: in the household of Saul also there was plainly an observance, at which David was expected. Since the "sacrifice," a communion-meal, was annually observed, we may conclude that this was New Year, falling at new moon. Obviously, then, the reckoning was by lunations, and the year was lunisolar.

If this conclusion be justified, this incident becomes doubly significant when we consider the character of the observance. The family communion-meal, which was David's excuse for absenting himself from the king's table, as well as the concurrent feast in the

[27] *Amos* 8, 5; *Hos*. 2, 11; *Isa*. 1, 13–14; 66, 23; *Ezek*. 45, 17; 46, 3.
[28] *2 Kings* 4, 23.
[29] *1 Sam*. 20.

royal household, where David likewise was expected because he had married the king's daughter, have obvious analogies with Passover, which likewise was an annual communion-meal observed anciently by families at the turn of the year. It is in fact not improbable that the feast here mentioned is no other than Passover as it was kept in the early times. That the calendary references were not deleted we may perhaps explain by the scribe's failure to recognize the occasion because of the changed manner in which Passover was celebrated in his time. At all events, we must in this connection consider the data of the older documents regarding the date of Passover. Here the prescription of *Deuteronomy*[30] is of special interest because, as we have seen, it antedates but little the reformation of Josiah: "Observe the *hodesh* of Abib, and keep the Passover unto Yahweh thy God; for at the *hodesh* of Abib Yahweh thy God brought thee forth out of Egypt by night." At least from the time of the Septuagint version it has been held that in this context *hodesh* means "month"; but it may be doubted whether the injunction would ever have been so interpreted except for the fact that in later Judaism Passover was celebrated, as it still is, at full moon. We have already pointed out that this practice was apparently not contemplated[31] even in the ordinance of the Priestly Code, which merely designated the day of the (originally conventional) month; for *Deuteronomy* that date has no significance whatever. Indeed, once the later practice is disregarded as irrelevant, it becomes plain that the traditional interpretation is untenable. The command of *Deuteronomy* has in view the *mo'ed* or tryst which Israel was bidden to keep with Yahweh in commemoration of the exodus: it is the commemorative feast that is to be observed. To bid the people "observe the month of Abib" is almost grotesque: so far as we know, Israel never observed a month of feasting. At most it was a day, but even this period was further limited; for Yahweh led his people forth "by night." Such precision as to the moment of the exodus coupled with such vagueness in regard to the time of the

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[30] 16, 1.

[31] Among the Babylonians the full moon was observed very much as was new moon. This may have had an influence on the Jews of the captivity, tending to facilitate the transfer of Passover from the latter to the former. If, however, the Church Year of the reformation was, as we have tried to show, instituted under Egyptian influences, the coincidence of the major *haggim*—Passover and Sukkot—with the full moon must have been undesirable, avoided rather than sought, because of the sacrifice of swine to Set Typhon at full moon in commemoration of his finding the body of Osiris (Plutarch, *De Iside et Osiride*, 8).

commemoration is conceivable only with interpreters. Fortunately we know that *hodesh* is properly the term for "new moon"; and we affirm with perfect confidence that *Deuteronomy* appointed the new moon of the first (lunar) month of the year as the time for the celebration of Passover, the ancient New Year's festival.

In this *Deuteronomy* agrees with the other prescriptions for the keeping of Passover contained in the most ancient documents, where we read, for example, "This day ye go forth at the *hodesh* of Abib." [32] The exodus, as has already been pointed out, begins and ends with Passover: this is because the sacred story reflects the ritual observances of the *hag*, which consisted, among the Israelites as among the Babylonians and Egyptians, of the going forth (ἔξοδος) and return (νόστος) in procession, a form peculiarly appropriate for a *rite de passage* intended to see the Old Year out and the New Year in. In the older period, in which a lunisolar calendar was clearly in use, this ceremony, accompanied with a communion-feast for the clan and its invited guests, was held at the first new moon of the year, the vernal epoch. The autumnal epoch also was observed with a *hag* connected with the agricultural festival of ingathering at the turn of the year, but the data regarding it contribute nothing to our knowledge of the calendar. The psalmist[33] says that Yahweh appointed the moon for *mo'adim*, which applies equally well to the earliest and the latest practice, but not to the procedure at the time of the reformation; more vaguely it is stated in the story of creation[34] that the lights in the firmament of heaven—sun and moon—were to serve for signs and *mo'adim* and to mark days and years, a statement which, with slight differences of interpretation, would suit any period.

The calendar of Israel thus experienced several changes; but it was essentially based on a lunisolar year. For a brief time only did it rest on a solar year, when it adopted some of the forms of the Egyptian. This period, however, was so important, because it was that of the reformation of Josiah, that the calendary arrangements then adopted for the Church Year have persisted down to the present day, although the return to the lunisolar year during the exile led to the adoption of other calendary festivals unrelated to those of the "three times" of required pilgrimage and to a change in the interpretation of the older festival Torah which has been productive of

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[32] *Exod.* 13, 4; cp. 13, 5; 23, 15; 34, 18. See also *Exod.* 19, 1; 40, 2; *Num.* 29, 1; *Lev.* 23, 24.

[33] *Ps.* 104, 19.

[34] *Gen.* 1, 14.

much confusion. Many details there are which still remain obscure; but the history of the calendar in its main outlines is both clear and intelligible in the light of the political fortunes of Israel.

WESLEYAN UNIVERSITY.

After reading the page-proof, I obtained Julius Lewy's *Forschungen zur alten Geschichte Vorderasiens* [*Mitteilungen der Norderasiatisch-Aegyptischen Gesellschaft* (*E. V.*) *1924, 2, 29 Jahrgang*], *1925*. Had I had access to this study sooner, I should have modified my statement regarding the Battle of Megiddo, and might have spoken with greater confidence of the influence of Egypt at the moment when the calendar of the reformation was adopted.

W. A. H.

Dec. 12, 1925.

Proceedings of the American Academy of Arts and Sciences.

Vol. 61. No. 3. February, 1926.

THE EFFECT OF PRESSURE ON THE VISCOSITY OF FORTY-THREE PURE LIQUIDS.

By P. W. Bridgman.

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Presented October 14, 1925. Received November 16, 1925.

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Introduction.

Among the non-thermodynamic properties of a liquid, the viscosity is one of those which might be expected to be of most significance, and is one which has been most studied experimentally. There are various lines of evidence which suggest that the viscosity of a liquid is more intimately connected with the specific properties of the molecules than is the viscosity of a gas. It is known that the mechanism of viscous resistance in a liquid must be different from that in a gas, but there are no theories at present capable of giving an adequate account of the phenomena. It is to be expected that the information given by the change of viscosity produced by pressure will be especially significant, since under pressure the molecules are brought into closer contact, and any peculiarities in their specific relations accentuated. There have been, however, only a few measurements of the effect of pressure on the viscosity of pure liquids, and these over only a comparatively small range of pressure.[1] The effect of pressure on the viscosity of a number of lubricating oils has been recently determined over a range sufficient to change the viscosity many fold,[2] but oils are not simple substances, and the results obtained with them cannot be easily interpreted, although information of this character is evidently of much importance technically.

In this paper the effect of pressure has been studied on some forty-three pure liquids, most of them organic, but including water. In

addition, petroleum-ether and kerosene have been studied because of their interest in connection with high pressure apparatus. The method used has demanded that all the liquids be electrical non-conductors. The range of the measurements is 12000 kg./cm.^{2} (unless the liquid freezes at a lower pressure, as is often the case), and measurements have been made at 30° and 75°, thus giving both the effects of pressure and temperature. It may be said in general that the effects of pressure on viscosity are greater than on any other physical property hitherto measured, and vary very widely with the nature of the liquid. The increase of viscosity produced by 12000 kg. varies from two or three fold to millions of fold for the liquids investigated here, whereas such properties as the volume decrease under 12000 seldom vary by as much as a factor of two from substance to substance.

The Method and the Apparatus.

None of the methods previously used for the measurement of the effect of pressure on viscosity was adapted to the greater pressure range of this work, in general the apparatus being too bulky or too cumbersome in operation, requiring for example that the pressure chamber be reopened and the apparatus refilled for every new determination at a new pressure. The apparatus adopted does not give the absolute viscosity, but does give the relative viscosity, which is all we are interested in here, and is shown in Figure 1. The general idea of the method is very simple; in a steel cylinder of approximately 6 mm. internal diameter, filled with the liquid under investigation, there is a steel cylindrical weight separated from the walls of the cylinder by a narrow annular space. The time of vertical fall of the weight from one end of the cylinder to the other is determined; the time is a measure of the viscosity.

The pressure producing apparatus is so mounted and connected with the viscosity cylinder that it may be rotated through 180°, so that after the time of fall of the weight has been determined the apparatus may be reversed, and the time of fall in the opposite direction determined. This may be repeated as often as desired, allowing an indefinite number of readings at any pressure with the same set-up.

The time of fall is determined electrically. At each end of the cylinder there is an electrically insulated terminal *D* against which the weight rests at the end of its fall. In this position electrical connection is made from the walls of the cylinder through the weight to the terminal, and the completion of this connection may be made to

operate a suitable timing device. It is necessary, therefore, that the weight be in close enough contact with the cylinder to permit

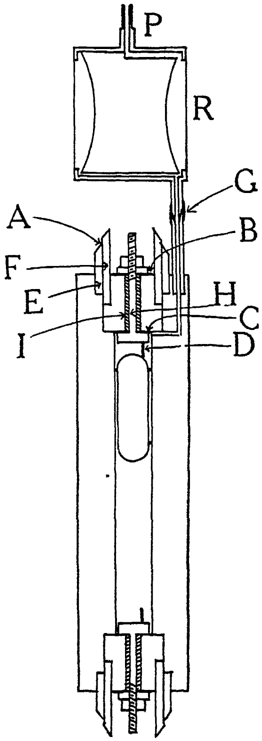

FIGURE 1. Section of viscosity apparatus.

passage of current, but at the same time be capable of free fall. With the electrical arrangements used it was necessary that the contact

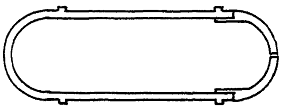

FIGURE 2. Detail of falling weight of viscosity apparatus.

between weight and cylinder be closer than 0.0025 cm. The weight, Figure 2, was provided with three small projecting lugs* at the top

* Shown as two in the figure for convenience of drawing.

and bottom ends, which act as guides to keep the weight concentric as it falls, and through which electrical contact is made with the cylinder. By putting the stop D against which the weight rests at the end of its fall off center, it was ensured that the lugs on one side of the weight were pressed more firmly against the cylinder, thus making better contact. In order to keep the time of fall within reasonable limits, different weights were used according to the absolute viscosity of the liquid, the annular space between weight and cylinder varying between 0.0125 cm. for water to 0.075 cm. for the more viscous liquids such as glycerine. There was further provision for variability in the viscosity of the liquid by making the weight hollow (see detail in Figure 2), and changing its total weight by placing within the cavity appropriate weights of tungsten or gold. The hollow weight was made in two pieces, of the same material as the cylinder. The main body of the weight, with the lugs, was milled from one piece, and a cap to close the cavity was made a tight push fit for the body of the weight. The external shape of the cap was made as much like that of the other end as possible, but the two ends were never exactly alike, because for one thing it was necessary to provide a small hole in one end by which the interior might be filled. The times of fall in the two directions were, therefore, never exactly the same; the difference was not often more than one per cent.

The insulating plugs at the two ends of the cylinder are shown in the figure. It is the function of these plugs not only to provide a terminal electrically insulated from the cylinder, but to prevent the liquid under investigation in the cylinder from mixing with the pump liquid in which the cylinder is immersed. The central stem of the the plug, H, is of brass, with the projecting terminal of platinum, D, insulated by a sleeve of pipestone, I, and flat washers of mica B and C. The mechanical separation of the liquid inside from that outside is provided entirely by the washer C. The seats on which the mica washers rest are ground flat; the washers are made as tight as possible initially with the nut on the stem, and become still tighter under pressure because of the differential compressibility of the brass stem and the steel of which the surrounding parts of the apparatus are made. The insulating plug was soldered into the end of the cylinder; in this way the liquid under investigation came in contact only with metals or mica, and was kept pure. The soldering and unsoldering were facilitated by two german silver sleeves E and F permanently soldered to the cylinder and the plug respectively. The soldered connection between cylinder and plug was made and broken

at A. This could be easily done since in the first place german silver is easy to solder, and in the second place is a poor conductor of heat, so that the soldering could be done rapidly with a soldering copper without seriously heating the rest of the apparatus. The unsoldering was facilitated by a special soldering copper, of cylindrical shape to fit the sleeve.

The liquid under investigation, which fills the inside of the cylinder, must be kept from contact with the surrounding liquid by which pressure is transmitted, but at the same time must freely receive the pressure. This was done by means of a reservoir, R, of very thin pure tin, attached to the upper end of the cylinder as shown. The pressure is transmitted from the liquid on the outside to that on the inside through the tin walls of the reservoir, which offer so little resistance that the pressures outside and inside are the same within less than 1 kg./cm.[2] This device of the reservoir has already been used in connection with measurements of the effect of pressure on the thermal conductivity of liquids, and will be found described in greater detail in that paper.[3] The connection from the reservoir to the cylinder was through a tube of german silver; this connection, G, was resoldered and a new reservoir made at each new filling of the apparatus with a new liquid. The apparatus was filled through the fine tube, P, of german silver at the top of the reservoir. The filling liquid was placed in a glass thistle connected in such a way with rubber tubing to the pipe at the top of the reservoir that practically no liquid came in contact with the rubber, and then the whole combination was placed bodily under the receiver of an air pump. It was filled by exhausting the receiver, the air inside the cylinder bubbling out through the liquid in the thistle, and then readmitting air to the receiver, driving the liquid into the reservoir and the cylinder. The receiver was exhausted to such a point that the liquid boiled vigorously, and this was repeated a number of times, so that the liquid was nearly air free. The reservoir was then closed by soldering into the top of the pipe, P, a brass plug, the outside of the pipe being kept cool in a simple way with water, so that the liquid inside could not boil during the soldering. The cylinder and the reservoir, filled with the liquid, were now attached with screws to an insulating plug, not shown, but essentially like the one described in the paper on thermal conductivity. Soldered connection was made from the insulated terminals of the cylinder to the insulated terminals of the plug, and the plug, with cylinder and reservoir as one self-contained unit, were screwed into the large pressure cylinder.

The large pressure cylinder was connected with a pipe to the pressure generating apparatus and the pressure gauge, which were the same as that used in previous work. They were now mounted horizontally, instead of vertically, and were so arranged that they could be rotated about the connecting pipe as an axis. During this rotation the hydraulic press with which pressure was produced had to be disconnected from the hand pumps which were the source of pressure. This was made possible by valves mounted to rotate with the press, so that the pressure produced by the pump could be maintained after the transmitting pipe has been disconnected. The large pressure cylinder which contained the viscosity apparatus was T-shaped; there was a side connection at which entered the pipe connecting to the pressure producing apparatus, which acted as the long arm of the *T*, which was horizontal and about which rotation took place. The main body of the cylinder acted as the cross arm of the T, and by rotation was changed from one vertical position to the inverse. The falling weight within the viscosity apparatus fell along the axis of the cross arm of the T. The viscosity cylinder was kept at constant temperature by the conventional stirred bath and regulators; the horizontal connecting pipe entered the bath through a simple stuffing box.

The timing apparatus was a comparatively simple affair. A Warren clock, which is essentially a small motor running synchronously with the commercial 60 cycle alternating current source, was connected to the second hand shaft of an ordinary clock movement. The Warren clock made one revolution per second, so that the clock movement rotated at 60 times the normal speed. The circuit of the Warren clock was made and broken through a relay operated by the circuit in which was the falling weight of the viscosity apparatus. Since the Warren clock did not stop immediately when the circuit was broken, it was necessary to provide a mechanical stop; this was done by an arm with a pointed end pulled by a spring into the teeth of one of the gears of the clock movement. This was operated by a relay in series with the other relay. To provide against too great mechanical shock to the clock movement on stopping, there was a spring in the connection between the Warren clock and the clock movement. Since there were 60 teeth in the gear used for stopping purposes, the smallest time interval capable of being distinguished was 1/60 second, so that the necessary error in the determination of a single time interval was not over 1/120 second.

Considerable difficulty was found in getting a proper source of current to operate the relay through the contact made by the falling

weight. If the weight is to fall freely, there is considerable necessary contact resistance between the lugs and the walls of the cylinder. Direct current is not suitable, for if the voltage is high enough to jump the gap an arc follows, which may decompose the liquid or make the weight stick to the walls of the cylinder. After some trial, the alternating current delivered by a small bell ringing magneto of the type used in insulation testing was found suitable. The magneto was driven by a variable speed motor, connected through a belt and cone pulleys in such a way as to give a wide variation of speed. The speed was chosen as low as possible to give positive contacts, thus avoiding as much as possible contamination of the liquid by sparking. The use of such a source made it necessary to use in operating the Warren clock a relay sensitive to alternating current; an old telephone relay was found suitable.

There were various possible sources of error in the starting and stopping of the clock and the operation of the various relays, so that a calibration of the timing device was necessary. This was done by means of a second Warren clock, also rotating at one revolution per second. To the axle of this was attached a copper disc, one quarter of the periphery of which was insulated from the rest. Contacts made from the axle to the periphery gave a current which during every second was interrupted for exactly one-quarter second. The calibrating device could be connected to the timing device instead of the weight of the viscosity apparatus, and thus the clock tested by measuring known intervals of ¼ second. The calibration was made by the measurement of 50 such intervals. The error in the timing apparatus depends on the speed of the magneto; in by far the majority of cases the error in the average of 50 readings was only a few thousandths of a second, and in the worst case it never exceeded 0.050 second. Of course the error in a single interval could be considerably more. Since the error in the timing device is an absolute and not a relative matter, it is much more serious at the short intervals. The procedure was adopted of calibrating the clock with 50 ¼ second intervals after every readjustment of pressure when the absolute time of fall was less than 5 seconds, and at less frequent intervals for longer falls. If the time of fall was less than 5 seconds, 50 fall times of the weight were measured. The error in the finally corrected time of fall could not have been more than 0.002 or 0.003 seconds.

In addition to the corrections of the timing device there were a number of other corrections. What is desired is to so correct the measured time of fall that the finally corrected value shall be propor-

tional to the viscosity of the liquid at different pressures and temperatures. This demands, among other things, that the weight be falling for the entire time under a constant force with a constant velocity. Under the actual conditions the weight did not fall for the entire distance under a constant force, because while the cylinder was being rotated to start a new fall the weight started to fall before a completely vertical postition was reached, and therefore was falling under a diminished effective gravity until the completely vertical position was reached. The correction for this effect could be determined by measuring the time interval between the weight starting to fall and the cylinder reaching a completely vertical position. This was done electrically in a simple way by measuring, with the same timing apparatus as was used to time the falling weight, the interval between breaking of contact by the weight as it began to fall, and the reaching of a vertical position, which could be determined by making the rotating part come against a stop at the end of its rotation. Since the rate of rotation during the last part of the 180° inversion was approximately constant, the time of fall was corrected by subtracting from the measured time interval one-half the interval between starting to fall and reaching the completely vertical position. This correction so determined was 0.05 second.

Another correction is that due to the inertia effect at the beginning of fall. Because of the inertia of the weight a certain amount of time is needed to build up the final velocity. The correction may be determined theoretically from the equation of motion of the falling weight in a vscous liquid, and with the dimensions used was very small. The distance of free fall was 3 cm. In only one or two cases in these experiments was a time of fall used of less than one second. The correction for the acceleration effect is — 0.003 second for a fall time of 1 second, — 0.0015 at 2 seconds, and inappreciable above this.

The corrections so far discussed are important only at short times of fall. The largest correction is for the change of buoyancy of the liquid on the falling weight as the density of the liquid changes under pressure or with temperature. This correction is a percentage correction and is naturally greatest at the highest pressures. It may be shown that the exact expression for the correction, which is somewhat more complicated, reduces to the simpler form:

$$\frac{\rho_p - \rho_0}{\rho_0}\left[\frac{\dfrac{W_1}{D_1}+\dfrac{W_2}{D_2}}{\dfrac{W_1+W_2}{\rho_0}-\left(\dfrac{W_1}{D_1}+\dfrac{W_2}{D_2}\right)}\right],$$

with an error of less than 1% of the correction. This is accurate enough, since the total correction does not rise to over 5%. In this formula W_1 is the weight of the hollow steel shell, and D_1 the density of the steel, W_2 the weight and D_2 the density of the core of the shell (either of tungsten or gold), ρ_0 is the atmospheric density of the liquid and ρ_p its density under pressure. The compressibility of the metal of the falling weight does not enter within the limits of error.

In the following, the relative viscosities for any liquid are expressed in terms of the viscosity at 30° at atmospheric pressure as unity. The results of the run at 75° were corrected by a double application of the above formula; a first application corrected the viscosity at atmospheric pressure at 75° for the change in buoyancy of the liquid due to thermal expansion at atmospheric pressure (this correction was very small), and a second application then corrected the readings obtained under pressure for the change of density of the liquid produced by pressure at 75°. Within the limits of error, the percentage correction for the pressure effect is the same at 30° and 75°.

The compressibility of about a dozen of the liquids of this investigation have already been measured,[4] so that for these liquids the pressure correction could be exactly computed. The compressibility of the other liquids has not been measured to high pressures, so that for them some sort of estimate had to be made of the correction. This estimate could be made with considerable confidence because it is known that $(\rho_p - \rho_0)/\rho_0$ as a function of pressure does not vary greatly from liquid to liquid among such organic liquids as those used here. The procedure in calculating the correction for a liquid whose compressibility had not been measured was to substitute into the formula above the value of ρ_0 of the liquid (obtained from the tables) and to use for $(\rho_p - \rho_0)/\rho_0$ the corresponding value for that one of the twelve liquids whose compressibility had been measured which was most nearly like the liquid in question. In selecting the most similar liquid, weight was given both to the chemical constitution and to the compressibility at low pressures in those cases in which this had been determined by other observers. It was not difficult to select a similar liquid in practically every case except that of glycerine. The low pressure compressibility of glycerine is so much less than that of any other of the liquids that an estimate of the correction did not seem safe, and the compressibility was therefore determined by special experiment, and will be described in detail later.

The correction for buoyancy rises to as much as 5% in only a few

extreme cases. It was found by trial that the correction could be determined with an error of less than 0.1% in the final result over the entire range by actually computing it at only 2000, 6000, and 12000 kg., and then passing a smooth curve through the four points (the correction is zero at atmospheric pressure). It must be recognized that in some cases the error in the estimated correction may, because of an incorrect assumption about the compressibility, be over 0.1%, although I do not believe that this is often the case. For this reason, the corrections assumed for buoyancy are listed with the final data for each liquid together with the falling weights, so that at some future time, when the compressibility has been exactly determined, a more exact correction may be applied if necessary.

In computing the temperature correction for buoyancy at atmospheric pressure the effect of the thermal expansion of the steel is negligible, and only the thermal expansion of the liquid affects the result. The correction tends to become large when the density of the liquid is high, and small when the falling weight is of high density, as when a gold or tungsten core were used. The volume expansion of most of the liquids of this paper, with the exception of water, is about 5% between 30° and 75°, and this value was assumed for all except water. The correction was calculated by combining this value for the expansion with the particular weight and initial density of each liquid. The correction is 0.5% for nearly all the liquids, but for a substance with so extreme a density as ethylene dibromide rose to a maximum of 1.8%.

Finally a correction has to be applied for the change of dimensions of the apparatus under pressure. Since the cylinder and the weight were made of the same material (it is only the change of the *external* shape of the falling weight which is effective and so the core need not be considered), and since the pressure is hydrostatic, only the absolute dimensions of the apparatus change under pressure but the geometrical proportions remain unaltered. The way in which the time of fall varies with the absolute dimensions may be found by a dimensional argument. The time of fall, t, is a function of the viscosity of the liquid, η, the absolute linear dimensions, l, various dimensionless shape factors, and the total force, f, with which gravity pulls on the falling weight. Writing out the dimensions of η and f in terms of mass, length, and time, we see that

$$t \propto \eta f l^2.$$

The time of fall is therefore proportional to the square of the linear

dimensions. Under pressure the linear dimensions become smaller, and so the time of fall becomes smaller. Hence the observed time of fall under pressure is to be corrected by adding a percentage amount equal to twice the linear compression of the steel of the cylinder at the pressure in question. This correction is linear with pressure, independent of the temperature, and at 12000 kg. is 0.46%.

In addition to the corrections described above peculiar to these measurements of viscosity, there are other corrections common to all high pressure measurements, which have been described in sufficient detail previously.[5] All the corrections together do not amount to over 10% in the extreme case, and more often were of the order of 3 or 4%.

Experimental Procedure.

The first operation of a pressure run was filling the viscosity cylinder with the liquid. This had to be done with extreme care to avoid the introduction of bits of mechanical dirt which might hinder the free fall of the weight. In the preliminary work a good many unsuccessful attempts were made before the appropriate procedure was found. The apparatus was first disassembled from the preceding run by unsoldering the insulating plugs and the tin reservoir. The inside of the cylinder, which is brightly polished, was scoured with a linen rag and whiting powder, and then all loose particles wiped out with a clean linen rag and a camel's hair brush. The brass terminals and the flat faces of the insulating plug were polished bright with the finest French emery paper. The reservoir was remade by unsoldering the thin tin wall, partially deformed from the previous run, and brightly scouring with French emery paper the top and bottom plates and the central core. The reservoir was now resoldered with a new tin wall, using no flux in the soldering, which might partially penetrate into the interior of the reservoir, contaminating the liquid and depositing a gum which would interfere with the free fall of the weight. To facilitate soldering, the various parts which were to come in contact were previously tinned, using a flux in this preliminary tinning, because any excess could be readily wiped away. A weight of the dimensions judged to be most appropriate for the liquid under investigation was now selected, using as a criterion the known viscosity of the liquid at atmospheric pressure, and the apparatus was assembled by soldering in the plugs and the reservoir. During this assembly, which was made in a very bright light, preferably sunlight, the most rigorous scrutiny was made for minute particles of dirt, which were removed with the camel's hair brush.

The cylinder was now filled by exhausting as already described, and was then connected to the insulating plug which closes the pressure cylinder and was assembled into the pressure apparatus. This was usually done the last thing at night. In the morning a viscosity reading was made at once at the prevailing temperature of the room, which was 15° to 20°. The temperature of the bath was then raised to 30°, and after temperature equilibrium was reached another viscosity determination was made at atmospheric pressure. Pressure was now applied and a run made at 30° to 12000, or to the maximum pressure allowed by the freezing of the liquid. The freezing pressure was known in those cases in which the liquid had been previously investigated, but in a number of cases the freezing had not been previously investigated, and in the following will be found a number of new freezing points under pressure approximately determined. To have made an exact determination would have taken a great deal of time for the apparatus is not well adapted to this sort of measurement. Freezing is, of course, shown by the weight refusing to fall. There is no previous warning of the approach of freezing, but the viscosity curve of the liquid runs without change into the subcooled region. In the following the melting pressures are recorded as for example "freezes between 8000 and 10000 kg." or "melts between 7000 and 6000 kg." The first means that the substance was liquid at 8000 and on increasing pressure to 10000 it froze. The second means that at 7000 it was solid, and on releasing pressure to 6000 it melted. Because of the possibility of the supercooling of the liquid, the second method of determination is of course much the more accurate.

The number of pressure readings depended to some extent on the character of the liquid, more points being taken for a liquid whose viscosity changes rapidly with pressure or which could be measured over only a small range because of freezing. For those liquids which could be investigated over the entire pressure range of 12000 kg., readings were made at 0, 100, 500, 1000, 2000, 4000, 6000, 8000, 10000, and 12000 kg. If log viscosity is plotted against pressure a curve will be obtained nearly straight above 4000, but below this there is more or less curvature; this is the reason that the readings were multiplied at low rather than high pressures. In making the runs with the first few substances, pressure was released after the reading at the maximum of 12000, and check readings were made on the way down at 6000 and 0. There is no reason why a perfect check should not be obtained, unless the reservoir leaked or some

similar accident took place, because we are here dealing with the properties of a liquid which never have hysteresis. As a matter of fact, a perfect check was always obtained. The check readings having shown themselves unnecessary, in the case of the rest of the liquids, after the reading at 12000 and 30°, the temperature of the bath was changed to 75°, and the viscosity determined at 75° in decreasing pressure steps, retracing the steps of the ascending run to atmospheric pressure, if the boiling point of the liquid at atmospheric pressure was above 75°, or making the last reading at a pressure of a few atmospheres if the atmospheric boiling point was below 75°.

If the time of fall of the weight was less than 5 seconds, the time of 50 falls was taken, grouping the falls into five groups of ten. Above 5 seconds fall time, the mean of 10 fall times was taken, until the time got to be 40 or 50 seconds, when a smaller number of readings was taken, but never less than two even in the extreme case of one and a half hours. It has already been explained that the time of fall in the two directions might be slightly different because of lack of perfect symmetry in the two ends of the weight.

In the preliminary experiments a number of questions about the correct functioning of the apparatus were examined. In the first place it was established that the results could be repeated in that the apparatus could be taken apart and reassembled with the same liquid and the same readings obtained. If the falling weight was changed, either by changing the outside dimensions of the weight, or by putting a weight in the cavity keeping the outside dimensions the same, consistent results were obtained in that the ratio of the fall times at two different pressures was a constant.

Additional important checks are obtained by comparing the relative viscosities for different substances with those found by other observers. Nearly three-quarters of the readings were made with the same hollow weight, varying the total weight by the use of different cores. The relative times, corrected for the buoyancy of the liquid and the difference of total weight, of all these runs should be the same as the relative absolute viscosities determined by other observers. In Table I are given the corrected times of fall at 30° at atmospheric pressure, the absolute viscosity at 30° taken from the Smithsonian Tables, and the ratio of these two numbers for each liquid. The ratio should be constant, and the table shows that it is, except in one or two cases, with an error not greater than the usual discrepancy between viscosity determinations by different observers.

Another check is afforded by comparing the temperature coef-

ficient of viscosity at atmospheric pressure given by these experiments with the values of others. In Table II the ratio of the viscosity at 30° to that at 75° for some of the liquids of this investigation is compared with all the values given in the Smithsonian Tables for the same liquids. Again the agreement is satisfactory.

TABLE I.

COMPARISON OF RELATIVE VISCOSITIES OBTAINED WITH THE PRESSURE APPARATUS WITH THE ABSOLUTE VISCOSITIES OF OTHER OBSERVERS.

Liquid	Corrected Time of Fall at 30° (seconds)	Viscosity at 30° $\times 10^2$	Ratio $\frac{\text{Time}}{\text{Viscosity}}$ $\times 10^3$
Ethyl Alcohol	10.4	1.003*	1.04
n-propyl Alcohol	17.4	1.779	.98
n-butyl Alcohol	22.2	2.24	.99
i-propyl Alcohol	17.2	1 757	.98
i-butyl Alcohol	28.9	2 864	1 01
n-pentane	2.17	220	.99
n-hexane	2.79	.296	.94
n-octane	5 00	.483	1 04
i-pentane	2.18	.200	1.09
Ethyl Bromide	3.74	.368	1 02
Ethyl Iodide	5.52	.540	1.02
Ethyl Acetate	4.23	.407	1 04
CCl_4	8.65	.845	1 02
Chloroform	5.48	.519	1 06
CS_2	3.43	.352	.97
Ether	2.19	.223	.98
Benzene	5.72	.566	1.01
Toluene	5.53	.523	1 06
o-xylene	7 25	.709	1.02
m-xylene	5 92	552	1.07
p-xylene	5.74	568	1.01

The satisfactory functioning of the apparatus having been established, runs were made in the great majority of cases with only a single filling of the apparatus for a single substance.

It is not easy to estimate the probable accuracy of the relative

* The numbers in this column were obtained mostly from Smithsonian Tables or from Table III of this paper.

TABLE II.

COMPARISON OF TEMPERATURE COEFFICIENT OF VISCOSITY AT ATMOSPHERIC PRESSURE GIVEN BY THE PRESSURE APPARATUS WITH VALUES OF OTHER OBSERVERS.

Liquid	η_{30}/η_{75} Pressure Apparatus	Other Observers
Ethyl Alcohol	2.20	2.13*
n-propyl Alcohol	2.52	2.65
n-butyl Alcohol	2.84	2.81
i-propyl Alcohol	3 14	3.14
n-octane	1.55	1.58
Ethyl Iodide	1 46	1.44
CCl_4	1.74	1 69
Benzene	1.72	1.68
o-xylene	1.71	1 64
m-xylene	1.59	1.55
p-xylene	1.60	1.54
Toluene	1.60	1.56

viscosities under pressure yielded by these experiments. The maximum discrepancy in the time intervals was of the order of 0.5 seconds (10 intervals for fall times below 5 seconds, and single intervals above 5 seconds) giving a probable error in the averaged time of fall of something of the order of 0.05 second. The percentage error which this introduced into the final result depends on the total time of fall. As given in the following, the relative viscosities are the ratios of the corrected times of fall under the pressure and temperature in question to t_0, the corrected time of fall at atmospheric pressure at 30°. The percentage accuracy of these ratios obviously depends on the absolute value of t_0. In order to permit an estimate of this accuracy the value of t_0 is tabulated for each of the liquids. In Table V, to be given later, the logarithm to the base 10 of the relative viscosity is given as a function of pressure and temperature; one need expect no appreciable error in the shapes and relative positions of the log viscosity curves for times above 10 seconds. In addition to the accidental time errors, there may be consistent errors due to the various corrections; the more uncertain of the corrections are absolute and not percentage corrections, and so also are more important at the low

* Taken from Smithsonian Tables.

pressure end of the curves. Errors of this kind I believe to be considerably less than 0.01 seconds.

Some internal evidence as to probable accuracy is given by the closeness of the experimental points to a smooth curve. In constructing the table, the $\log_{10}$ of the corrected time of fall was plotted against pressure, smooth curves were drawn through the points, and the values at regular pressure intervals tabulated. The average numerical deviation from a smooth curve of $\log_{10}$ time is given in the table. The smoothness and self-consistency of the results was such that the theory of probable errors shows the justifiability of keeping more significant figures than are given here (logs to only three places are given), an uncertainty of 0.001 in the log corresponding to a percentage error of about 0.2%. The reason for not giving more significant figures was the very great increase of labor in computing the results which would have been involved. Three figures could be obtained fairly easily by direct graphical methods; another significant figure would have demanded computational methods at an enormous increase of time, which does not seem justified by any use which I can at present foresee will probably be made of these data.

In the case of water a great many experimental attempts were made, but an accuracy equal to that obtained with the other liquids was not achieved. The difficulty with water was caused by electrical conductivity of the water interfering with the operation of the timer through the electric contact arrangement. It was not possible to use the cylinder of bessemer steel used with the other liquids, because after the water had stood in contact with the steel for a while there was enough chemical action to produce a short-circuit in all positions of the weight. This was in spite of starting with water distilled in tin, from which all the air had been boiled out. Another viscosity cylinder was therefore made from one of the various grades of "rustless" iron recently put on the market. Considerable mechanical difficulty was found in machining this because of hard and soft spots, and the hole, although made as carefully as possible in the usual way with an ordinary reamer, was so much out of round as to introduce great irregularity, the weight falling freely in some positions, and in others sticking tight. A third apparatus was now made with another grade of rustless iron, this time the hole being *ground* true to within 0.00025 cm. To grind so long a hole as this to such an accuracy requires a high degree of mechanical skill, and I am much indebted to the firm of West and Dodge, who did the work. The falling weight was made of the same steel as the cylinder. But now

a great deal of trouble, not given by the first cylinder of rustless iron, was found with the electrical part of the apparatus; the apparatus would work perfectly in preliminary trials, but after running for a while the contact would fail. This was finally traced to the steel itself; after a number of sparks had passed between the cylinder and the weight a film was deposited of such highly insulating properties that it could not be broken down with any voltage feasible with the magneto. The steel of which the weight was formed was uneven in quality, and the contaminating film formed on the cap end in preference to the other. The difficulty was avoided at the low temperatures by making another cap of the original grade of rustless iron. With this, successful runs were made at 0° and 10°, but at 30° the insulation resistance became so great that the weight had to be discarded entirely, and a new one made of pure nickel. This worked well at 30°, but at 75° there was again trouble, both because of high insulation resistance to the falling weight, and electrolytic conductivity through the water. Only readings at pressures below 9000 were obtained at 75°, and these are in considerable doubt.

In reducing the readings to give correct relative viscosities over the entire range, correction had to be made for the change of weight between 10° and 30°. I made this correction so as to give between 10° and 30° the relative change of viscosity given by Bingham and Jackson.[6] For the relative changes between 0° and 10° and between 30° and 75°, the values given by these experiments were used. This gives a temperature coefficient of viscosity agreeing fairly well with that of Bingham between 30° and 75°, but materially larger between 0° and 10°.

Description of the Liquids.

There follows now a description of the various liquids used. These were obtained from various sources and were of varying degrees of purity. Fourteen of them were obtained through Professor J. Timmermans of the Bureau Belge d'Étalons Chimiques, for whose courtesy in providing me with the liquids I am much indebted; these were of an unusually high degree of purity. They were furnished in sealed glass tubes of approximately 10 cc. capacity. The tubes were not opened until immediately before filling the viscosity apparatus. The total time from breaking the glass seal to finally sealing the liquid into the viscosity apparatus was of the order of 5 minutes. Some of the physical constants of these liquids were determined by Professor Timmermans, and are given in the following table.

To Professor F. Keyes of the Mass. Institute of Technology I am indebted for CS_2, methyl and ethyl alcohol, ethyl ether, and normal pentane, also in sealed glass receptacles. These are also of a high degree of purity; the preparation and properties have been previously described by Professor Keyes.[7]

TABLE III.

PHYSICAL CONSTANTS OF LIQUIDS FROM BUREAU BELGE D'ÉTALONS CHIMIQUES.

Compound	Boiling Point	Densities			Viscosities $\times 10^5$	
		0°/4°	15°/4°	30°/4°	15°	30°
n-butyl alcohol	118°.10 (762 mm.)	0.8245	0.8134		3309	2237
n-amyl alcohol	137.27±.02 (751 mm.)	0.8395	0.8245			
i-pentane	27.95±.02	0.6393	0.62485			
Ethylene dibromide	132.00±.02		2.1911	2.1596	1880	1490
Ethyl acetate	77 15±.01	0.9245	0.9066			
n-butyl bromide	101 65±.02	1.3041	1 2830		626	537
CCl_4	75 75± 01	1.6326	1.6035		1040	845
Chloroform	61 20±.01	1 5264	1 49845			
n-amyl ether	185.26±.02 (750 mm.)	0 7990	0.7869			
Cyclohexane	80.75±.01		0.7830	0.7696	1056	828
Methyl cyclohexane	101.18±.01	0.7865	0.7734	0.7603	777	639
Benzene	80 15± 01		0.8841	0.8685	696	566
Chlorobenzene	132 00± 01	1 1280	1 1117	1.0954	844	711
Bromobenzene	156 15±.01	1 5200	1 5009		1196	985
Toluene	110 80± 01	0 88545	0.8716	0 8577	623	523
p-xylene	138 16± 01 (757 mm.)		0.8642	0.8526	682	568

The i-propyl alcohol I owe to Professor R. F. Brunel. This is from the same lot as that which I used previously in determining the effect of pressure on thermal conductivity. It was freshly distilled for this work in a Hempel column; and all came over at a temperature constant within 0.1°, the error of the thermometer.

Glycerine was Kahlbaum's purest, in a glass stoppered bottle.

The water was obtained from the Chemical Laboratory of Harvard University, and had been distilled in tin. There would have been no point in attempting to start with water of greater purity because of the impurities immediately absorbed by the water from the walls of the cylinder.

The other chemicals were obtained from the Eastman Kodak Co. and were of the best grades of those described in their catalogue of chemicals. The boiling points given in the catalogue for the liquids used here are reproduced.* In some cases the liquids were provided in glass stoppered bottles, but more often a cork stopper was used, separated from the liquid by a piece of paper. In such cases there was likely to be more or less mechanical dirt mixed with the liquid. Inclusion of any of this dirt in the viscosity apparatus was in almost all cases avoided by letting the bottle settle for some time, and then removing the liquid with a pipette, but in one or two cases an additional filtering was made through glass wool. Evidence of the purity of the liquid was in some cases obtained from the sharpness of freezing under pressure. If the liquid freezes sharply there are no pressures at which the weight will perceptibly leave one end of the cylinder (break contact), without falling completely to the other end, whereas if freezing is not sharp (liquid becomes mushy) the weight may break contact without falling completely to the other end.

Numerical Results.

The numerical results for all the substances except water are now given in Table V. The table gives $\log_{10}$ of the relative viscosity as a function of pressure and temperature, the viscosity at 30° and atmospheric pressure being taken as unity. The logarithm of the viscosity instead of the viscosity itself is given because the variation with pressure of the viscosity is very rapid, and the curve of viscosity against pressure has rapidly varying curvature, whereas the curve of log viscosity against pressure approaches a straight line at high pressure and is not too much curved at the low pressures. The pressures tabulated in the table are 0, 500, 1000, 2000, 4000, 6000, 8000, 10000, and 12000 kg./cm.^{2}, the intervals being shorter at the lower end of the range because of the much more rapidly varying curvature. From the values of the logarithms the ratio of the viscosity at atmospheric pressure at 30° to that at 75° may be found, and is tabulated. In the table are given the average numerical deviations from smooth curves of the observed logarithms. The deviation is usually not as much as 0.001 on the logarithm, and in general the observed points lay on a smooth curve within 0.1%. Since the accuracy of the time measurements depends on the absolute value of the time interval, the time of fall at 30° at atmospheric pressure (t_0) is given. For those substances with a relatively low value of t_0 the lower ends of the curves are relatively inaccurate, but there is

*See Table on p. 99.

TABLE V.

Substance		Pressure, kg./cm.² 1	500	1000	2000	4000	6000	8000	10000	12000	Average Deviation Smooth Curve	η_{30}	t_0	Wt.	Buoyancy Correction
Methyl Alcohol	$\log \frac{\eta}{\eta_0}$ 30°	000	094	.167	.286	.471	616	750	874	.998	.001			B	.0048
	$\log \frac{\eta}{\eta_0}$ 75°	9 769	9 862	9.933	043	.208	334	448	555	.655	.001	00520	1 73	C	.0130
	η_{30}/η_{75}	1 702	1 706	1 714	1 750	1.832	1 914	2 004	2 084	2.203					.0204
Ethyl Alcohol	$\log \frac{\eta}{\eta_0}$ 30°	000	.107	200	.363	617	829	1 023	1.211	1.390	.000			A	.0093
	$\log \frac{\eta}{\eta_0}$ 75°	9 657	9 772	9 873	045	.289	.473	.634	.778	.919	.000	01003	3 95	E	0236
	η_{30}/η_{75}	2 203	2 163	2 123	2 080	2.128	2 270	2.449	2.710	2.958					.0359
n-propyl Alcohol	$\log \frac{\eta}{\eta_0}$ 30°	.000	.151	283	.494	836	1.131	1 402	1.667	1.915	000			A	.0051
	$\log \frac{\eta}{\eta_0}$ 75°	9.598	9 754	9.880	074	.368	.610	827	1.033	1 223	.000	.01779	6.19	C	0121
	η_{30}/η_{75}	2.523	2 495	2.529	2 630	2.938	3 319	3 758	4 305	4.920					.0179
n-butyl Alcohol	$\log \frac{\eta}{\eta_0}$ 30°	000	.175	.321	.554	.934	1 289	1 609	1.912	2 208	.000			A	004
	$\log \frac{\eta}{\eta_0}$ 75°	9 548	9.724	9 867	.089	312	.690	941	1 172	1.396	.000	.02237	2.90	D	.010
	$\eta_{30}/_{75}$	2 845	2 838	2 858	2 932	3 343	3 991	4 679	5 521	6.518					.015
n-amyl Alcohol	$\log \frac{\eta}{\eta_0}$ 30°	.000	188	.341	.607	1.060	1.448	1 811	2.164	2 495	.000				.0087
	$\log \frac{\eta}{\eta_0}$ 75°	9 540	9.723	9 871	.105	.466	772	1 049	1 313	1 562	.000		2 29	F	.0212
	η_{30}/η_{75}	2 884	2 917	2 951	3 177	3 926	4.742	5 781	7 096	8 570					.0320
i-propyl Alcohol	$\log \frac{\eta}{\eta_0}$ 30°	.000	193	343	591	.982	1 318	1.640	1.977	2 311	.000			A	.004
	$\log \frac{\eta}{\eta_0}$ 75°	9 505	9 695	9 851	087	.425	701	957	1 191	1 424	.002	.01757	2 24	D	.011
	η_{30}/η_{75}	3 141	3 164	3 120	3 208	3 624	4 161	4 844	6 140	7 748					.015
i-butyl Alcohol	$\log \frac{\eta}{\eta_0}$ 30°	.000	210	.388	.696	1 203	1 655	2 075	2 483	2 898	.000			A	.0042
	$\log \frac{\eta}{\eta_0}$ 75°	9.444	9 659	9.824	.075	.488	838	1.158	1.459	1.747	.000	.02864	3 78	D	0103
	η_{30}/η_{75}	3.597	3 556	3 664	4 178	5.188	6 561	8.260	10 57	14.16					.0153

TABLE V.—*Continued.*

Substance		Pressure, kg./cm.[2] 1	500	1000	2000	4000	6000	8000	10000	12000	Average Deviation Smooth Curve	η_{30}	t_0	Wt.	Buoyancy Correction
i-amyl Alcohol	$\log \frac{\eta}{\eta_0}$ 30°	.000	.209	.386	.686	1 185	1.636	2.069	2.505	2 952	000				.0087
	$\log \frac{\eta}{\eta_0}$ 75°	9.424	9 618	9.787	.065	492	.848	1 168	1 483	1 780	000		.70	G	0211
	η_{30}/η_{75}	3 805	3 939	4 012	4 221	4 970	6 200	8 042	11 41	15.76					0316
n-pentane	$\log \frac{\eta}{\eta_0}$ 30°	.000	.181	.315	524	.847	1.112	1.360	1.615	1 846	.002				011
	$\log \frac{\eta}{\eta_0}$ 75°	9 811	014	.163	.380	676	.908	1.119	1 313	1.493	.000	00220	2.32	A	.027
	η_{30}/η_{75}	1.545	1.469	1 419	1 393	1 483	1 600	1 742	2 004	2.254					.040
n-hexane	$\log \frac{\eta}{\eta_0}$ 30°	.000	.184	.332	561	.914	1.224	1.514	1 803		.001				0105
	$\log \frac{\eta}{\eta_0}$ 75°	9.803	.028	.171	379	701	961	1.198	1.426	1 646	000	.00296	2.99	A	027
	η_{30}/η_{75}	1 574	1.432	1 449	1 521	1 633	1 832	2 070	2 382						.040
n-octane	$\log \frac{\eta}{\eta_0}$ 30°	000	.196	.327	.641	1.088	1 487				.000			A	.0043
	$\log \frac{\eta}{\eta_0}$ 75°	9 810	003	.153	390	.763	1 080	1 363	1.630		.000	00483	1.75	C	0119
	η_{30}/η_{75}	1 549	1 560	1 493	1 782	2 113	2 553								.0144
i-pentane	$\log \frac{\eta}{\eta_0}$ 30°	000	.202	.344	559	.894	1.175	1 431	1 687	1 947	.000				.0101
	$\log \frac{\eta}{\eta_0}$ 75°	9.821	.040	.193	408	715	.960	1.179	1 381	1.586	.000	.00198	2.34	A	.0258
	η_{30}/η_{75}	1 510	1.452	1 416	1 416	1.510	1 641	1.786	2 023	2 296					0398
i-amyl Decane	$\log \frac{\eta}{\eta_0}$ 30°	000	.237	.435	.772	1.354					.001			A	.0084
	$\log \frac{\eta}{\eta_0}$ 75°	9.772	9 989	178	463	.925	1.334	1.727			.000		2 65	E	.0210
	η_{30}/η_{75}	1 690	1 770	1 807	2.037	2.685									.0319
Ethylene Di-bromide	$\log \frac{\eta}{\eta_0}$ 30°	.000	.138								.001				.0296
	$\log \frac{\eta}{\eta_0}$ 75°	9 756	9 885	.003	.203	.354 (3000)					.000	.01490	20.6	A	.0739
	η_{30}/η_{75}	1.754	1.791								1 discard				.0837

TABLE V.—*Continued.*

Substance		Pressure, kg./cm.² 1	500	1000	2000	4000	6000	8000	10000	12000	Average Deviation Smooth Curve	η_{30}	t_0	Wt.	Buoyancy Correction
Ethyl	$\log \frac{\eta}{\eta_0}$ 30°	.000	.134	.242	.405	.649	.837	1.008	1.172	1.323	.001				0150
Chloride	$\log \frac{\eta}{\eta_0}$ 75°	9 850	.017	131	.285	.514	.683	.834	.977	1.111	.000		2.54	A	.0341
	η_{30}/η_{75}	1.413	1 309	1.291	1.318	1.365	1.426	1.493	1.567	1.633					.0443
Ethyl	$\log \frac{\eta}{\eta_0}$ 30°	.000	.121	.222	.387	.631	.854	1.043	1 223	1 400	.000				.0195
Bromide	$\log \frac{\eta}{\eta_0}$ 75°	9.806	9 959	.072	.235	.472	.653	.816	.978	1.123	.000	.00368	4.54	A	.0486
	η_{30}/η_{75}	1.567	1 452	1.413	1.419	1.442	1.589	1.687	1.758	1.892					0602
Ethyl	$\log \frac{\eta}{\eta_0}$ 30°	.000	.115	.218	.385	.656	888	1.108	1.330	1.549	.001			A	.0144
Iodide	$\log \frac{\eta}{\eta_0}$ 75°	9 837	9 954	.057	.227	.467	.672	.854	1.030	1.200	.004	.00540	2.15	C	.0363
	η_{30}/η_{75}	1.455	1.449	1.445	1.439	1.545	1 644	1.795	1.995	2.234					.0551
Acetone	$\log \frac{\eta}{\eta_0}$ 30°	.000	.135	.226	.373	.605	.804	.987	1.160		.000			A	.0051
	$\log \frac{\eta}{\eta_0}$ 75°	9 895	.017	.113	.245	.445	.610	.762	.898	1.031	.002	.00285	1.16	C	.0139
	η_{30}/η_{75}	1.274	1 312	1.297	1 343	1.445	1 563	1.679	1.828						.0213
Glycerine	$\log \frac{\eta}{\eta_0}$ 30°	.000	.134	.260	.497	.936	1.346	1.741	2.133		.000				0088
	$\log \frac{\eta}{\eta_0}$ 75°	8 810	8 920	9.023	9.204	9.529	9 818	.094	.369	.628	.001	3.8	9.42	H	0186
	η_{30}/η_{75}	15 49	16 37	17.26	19.63	25.53	33.73	44.36	58.08						0291
Ethyl	$\log \frac{\eta}{\eta_0}$ 30°	.000	.142	.258	.463	.818	1.120	1.393	1.686	1.974	.003			A	.0060
Acetate	$\log \frac{\eta}{\eta_0}$ 75°	9.836	9 976	.081	.253	.517	.761	.992	1.213	1.416	.000	.0039	1.50	C	.0151
	η_{30}/η_{75}	1.459	1 466	1.503	1.622	2.000	2.286	2.518	2.972	3.614					0229
n-butyl	$\log \frac{\eta}{\eta_0}$ 30°	.000	.143	.269	.474	.816	1.115	1.408	1.715	2.018	.000			A	.0088
Bromide	$\log \frac{\eta}{\eta_0}$ 75°	9.832	9.975	.090	.273	.564	811	1.040	1 264	1.484	.002	.00537	2.21	C	0214
	η_{30}/η_{75}	1.472	1.472	1 510	1.589	1.786	2.014	2.333	2 825	3.420					.0319

TABLE V.—*Continued.*

Substance		Pressure, kg./cm.² 1	500	1000	2000	4000	6000	8000	10000	12000	Average Deviation Smooth Curve	η_{30}	t_0	Wt.	Buoyancy Correction
Cineole	$\log \frac{\eta}{\eta_0}$ 30°	.000	.315								.002				.0099
	75°	9.654	9.905	142	.575						.000		2.03	F	.0241
	η_{30}/η_{75}	2.218	2.570												.0364
Oleic Acid	$\log \frac{\eta}{\eta_0}$ 30°	.000	.306	616							.000				.0103
	75°	9 419	9.671	9 989	.255	.843					.001		2.72	I	.0265
	η_{30}/η_{75}	3 811	4 315	4.236											0402
CCl_4	$\log \frac{\eta}{\eta_0}$ 30°	.000	.190	.351	.493 (1500)						000			A	.0095
	75°	9.760	9.949	.100	.349	542					.002	00845	3.26	C	0267
	η_{30}/η_{75}	1.738	1.742	1.782											.0529
Chloroform	$\log \frac{\eta}{\eta_0}$ 30°	.000	.110	.211	.386	.660	.884				.002			A	0104
	75°	9.858	9.985	.094	.251	.480	.691	.914	1.141		.000	.00519	2.05	C	0261
	η_{30}/η_{75}	1.387	1 334	1.309	1 365	1.514	1.560								0396
CS_2	$\log \frac{\eta}{\eta_0}$ 30°	.000	.090	.160	.307	.509	.674	.840	1 010	1.189	002				.0133
	75°	9.875	9.972	.051	180	.372	.527	.671	.808	.946	.000	.00352	4.05	A	.0375
	η_{30}/η_{75}	1.334	1.312	1.285	1.340	1.371	1 403	1.476	1 592	1.750					.0491
Ether	$\log \frac{\eta}{\eta_0}$ 30°	.000	.189	.324	.514	.792	1.042	1.261	1.469	1.670	.002				0109
	75°	9 878	.024	.149	344	.601	.806	986	1.155	1.311	.000	00212	2 38	A	.0258
	η_{30}/η_{75}	1.324	1.462	1.496	1.479	1.552	1 722	1 884	2.061	2 286					.0398
n-amyl Ether	$\log \frac{\eta}{\eta_0}$ 30°	.000	.218	.401	.708	1.230	1.685	2.091			.002			A	.0048
	75°	9.736	9.943	.107	364	.776	1.125	1.437	1.728	2.007	.000		3 44	C	.0114
	η_{30}/η_{75}	1.837	1.884	1.968	2 208	2.844	3.631	4.508							.0169

TABLE V.—*Continued.*

Substance		Pressure, kg./cm.² 1	500	1000	2000	4000	6000	8000	10000	12000	Average Deviation Smooth Curve	η_{30}	t_0	Wt.	Buoyancy Correction
Cyclo-hexane	$\log \frac{\eta}{\eta_0}$ 30°	.000	.261								000				.0063
	$\log \frac{\eta}{\eta_0}$ 75°	9.723	9.975	.169	341 (1500)						.002	.00828	9 18	A	0169
	η_{30}/η_{75}	1 892	1 932												
Methyl Cyclohexane	$\log \frac{\eta}{\eta_0}$ 30°	000	.220	388	.710	1.274	1.804	2 318			.003			B	.0037
	$\log \frac{\eta}{\eta_0}$ 75°	9 747	9 976	.154	434	.900	1 335	1 756	2.167	2.582	.000	.00639	2.14	C	.0100
	η_{30}/η_{75}	1 791	1 754	1.714	1 888	2.366	2 944	3 648							.0163
Benzene	$\log \frac{\eta}{\eta_0}$ 30°	.000	.173	347							.001				.0087
	$\log \frac{\eta}{\eta_0}$ 75°	9 765	9 938	.081	308	498 (3000)					.003	.00566	6 34	A	.0202
	η_{30}/η_{75}	1 718	1 718	1 845											
Chloro-benzene	$\log \frac{\eta}{\eta_0}$ 30°	000	133	253	.478	.867	1 223				.002			B	0099
	$\log \frac{\eta}{\eta_0}$ 75°	9 814	9.936	053	245	.563	852	1 146	1.465		.000	00711	2 38	C	.0208
	η_{30}/η_{75}	1.535	1 574	1 585	1.710	2 014	2.350								0312
Bromo-benzene	$\log \frac{\eta}{\eta_0}$ 30°	000	138	.262	486	897					.000				.0099
	$\log \frac{\eta}{\eta_0}$ 75°	9 801	9.930	044	.228	.558	.874	1 029 (7000)			.000	.00985	3 29	A	.0234
	η_{30}/η_{75}	1 581	1.614	1 652	1.811	2 183								C	.0346
Aniline	$\log \frac{\eta}{\eta_0}$ 30°	.000	195	376	709						.001			A	.0037
	$\log \frac{\eta}{\eta_0}$ 75°	9.551	9 703	9 847	102	.560					.000	.0319	4 08	D	0101
	η_{30}/η_{75}	2.812	3 105	3 381	4 046										.0162

TABLE V.—*Continued.*

Substance		Pressure, kg./cm.[2] 1	500	1000	2000	4000	6000	8000	10000	12000	Average Deviation Smooth Curve	η_{30}	t_0	Wt.	Buoyancy Correction
Diethyl-aniline	$\log \frac{\eta}{\eta_0}$ 30°	.000	.201	.394	.761	1 070 (3000)					002				.0110
	$\log \frac{\eta}{\eta_0}$ 75°	9 690	9 839	9 984	259	.758	1.250	1.775			.003		1.32	F	.0279
	η_{30}/η_{75}	2 042	2 301	2 570	3 177										.0424
Nitro-benzene	$\log \frac{\eta}{\eta_0}$ 30°	000	.134	.264							.001			A	.0045
	$\log \frac{\eta}{\eta_0}$ 75°	Decomposes											2.23		.0121
	η_{30}/η_{75}													D	.0194
Toluene	$\log \frac{\eta}{\eta_0}$ 30°	.000	.145	.274	.497	.897	1.285	1.699	2 177		.000			A	.0049
	$\log \frac{\eta}{\eta_0}$ 75°	9 796	9 939	.065	267	.597	896	1 186	1.504	1 832	.000	.00523	1 96		0137
	η_{30}/η_{75}	1 600	1 607	1.618	1 698	1.995	2 449	3 258	4 710					C	.0213
o-xylene	$\log \frac{\eta}{\eta_0}$ 30°	.000	.165	.311	577						.000			A	.0054
	$\log \frac{\eta}{\eta_0}$ 75°	9 767	9 925	057	.292	689	1 087				.001	00709	2 57		0131
	η_{30}/η_{75}	1 710	1.738	1 795	1 928									C	0196
m-xylene	$\log \frac{\eta}{\eta_0}$ 30°	000	.154	.290	529	967					.001				0092
	$\log \frac{\eta}{\eta_0}$ 75°	9.799	9 959	.079	286	.637	.983	1.333			.001	.00552	6 55	A	.0226
	η_{30}/η_{75}	1 589	1 567	1 626	1 750	2.138									.0336
p-xylene	$\log \frac{\eta}{\eta_0}$ 30°	000	.152								.000			A	.0054
	$\log \frac{\eta}{\eta_0}$ 75°	9.797	9 957	.092	315						.003	00568	2.01		.0130
	η_{30}/η_{75}	1 596	1 567											C	0196
p-cymene	$\log \frac{\eta}{\eta_0}$ 30°	.000	172	333	.626	1.194	1 859				.000			B	0059
	$\log \frac{\eta}{\eta_0}$ 75°	9.800	9 948	.087	.335	.749	1.168	1.612	2.164		.000		2.43		.0149
	η_{30}/η_{75}	1.585	1.675	1.762	1.954	2.786	4 977							C	0226

TABLE V.—*Continued.*

Substance		Pressure, kg./cm.² 1	500	1000	2000	4000	6000	8000	10000	12000	Average Deviation Smooth Curve	η_{30}	t_0	Wt	Buoyancy Correction
Eugenol	$\log \frac{\eta}{\eta_0}$ 30°	.000	.288	.541	1.081	2.273	3.007				.003				.0138
					1.652	(3000)	(5000)								
	$\log \frac{\eta}{\eta_0}$ 75°	9.429	9.616	9,810	.143	.805	1.520	2.343			.001		1.70	G	.0326
	η_{30}/η_{75}	3.724	4.699	5.383	8.670	29.38									.0496
Petroleum Ether	$\log \frac{\eta}{\eta_0}$ 30°	.00	.16	.30	.54	.93	1.28	1.59	1.88	2.18			2.75		(*)
	$\log \frac{\eta}{\eta_0}$ 80°					.56	.83	1.06	1.28	1.49					
	η_{30}/η_{80}					2.34	2.82	3.39	3.98	4.90					
Kerosene	$\log \frac{\eta}{\eta_0}$ 30°	.00	.24	.46	.88	1.71									
	$\log \frac{\eta}{\eta_0}$ 80°					.91	1.41	1.88	2.34	2.80			3.80		(*)
	η_{30}/η_{80}					6.3									

(*) No buoyancy correction applied.
Designation of Weights

A	1.014 gm. Fe	D	7.041 gm. Au	G	3.821 gm. Fe
B	.997 gm. Fe	E	1.921 gm. Fe	H	3.134 gm. Fe
C	2 008 gm. W	F	4.108 gm. Fe	I	3.470 gm. Fe

no error arising from this source in the relative values at the higher pressures. The falling weights are tabulated and in the last column the corrections assumed for the buoyancy of the liquid at 2000, 6000, and 12000 kg., respectively. For those liquids whose compressibility has not been directly measured a small correction may have to be made at some future time when the compressibility is measured, permitting a more accurate buoyancy correction. Also, for convenience in the discussion, the absolute viscosities at atmospheric pressure at 30° are listed when these are known; many of these values were taken from the Smithsonian Tables, and others were given by Timmermans.

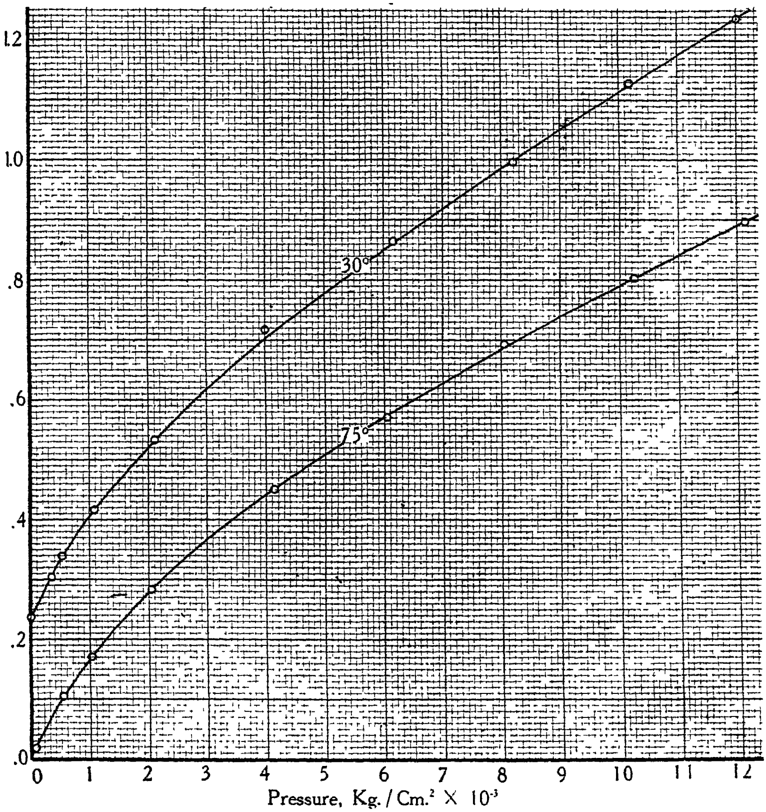

FIGURE 3. The common logarithm of the corrected time of fall of the weight against pressure for methyl alcohol. The time of fall is proportional to viscosity.

Sample curves for two substances, giving observed logarithm of the relative viscosity, are shown in Figures 3 and 4.

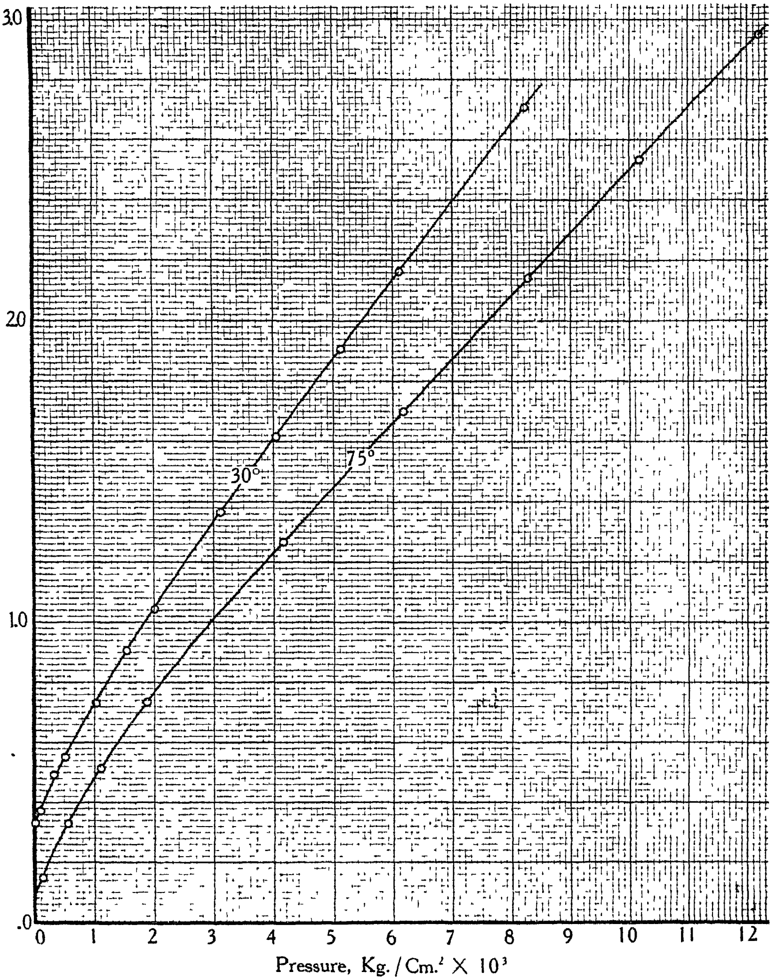

FIGURE 4. The common logarithm of the corrected time of fall of the weight against pressure for methyl-cyclohexane. The time of fall is proportional to viscosity.

Because of its comparatively small variation of viscosity with pressure, water is treated separately. In Table VI. are given the

relative viscosities (not log relative viscosity) as a function of pressure at 0°, 10°, 30°, and 75°. The pressure range at the two lowest temperatures was terminated by freezing, and at 75° the limit was set by the experimental difficulties already described. The experimental points are plotted in Figure 5. The experimental irregularity is much greater than for the other liquids which are better insulators, but still is not great enough to leave any doubt as to the essential character of the facts.

TABLE VI.

RELATIVE VISCOSITY OF WATER.

Pressure kg./cm.²	Relative Viscosity			
	0°	10.3°	30°	75°
1	1.000	.779	.488	222
500	.938	.755	.500	.230
1000	.921	.743	.514	239
1500	.932	.745	.530	.247
2000	.957	.754	.550	258
3000	1.024	.791	.599	.278
4000	1.111	.842	.658	.302
5000	1.218	.908	.720	.333
6000	1 347	.981	.786	.367
7000		1 064	.854	.404
8000		1 152	.923	.445
9000			.989	.494
10000			1 058	
11000			1.126	

Some of the liquids require special comment.

Methyl Alcohol. Two attempts were necessary with this. At first a portion of the same sample was used as had been used for the thermal conductivity measurements under pressure. This had been sealed in glass since extracting the thermal conductivity sample, but nevertheless had absorbed sufficient moisture from the air during that brief handling to make it so conducting that the method failed. A second fresh sample was obtained from Professor Keyes, also prepared in 1923, but sealed in glass ever since. This was a sufficiently good insulator to give good readings.

Ethyl Alcohol. At 75°, at a pressure of 2000 kg. and below, the electrical conductivity became so great that the electrical timing

device ceased to function, and a telephone and stop-watch had to be substituted. This gives less accurate results, the smallest division of the stop-watch being 0.2 seconds, so that the lower end of the 75° is much more in error than usual. The upper end of the 75° curve is not affected by this error, neither is any part of the 30° curve.

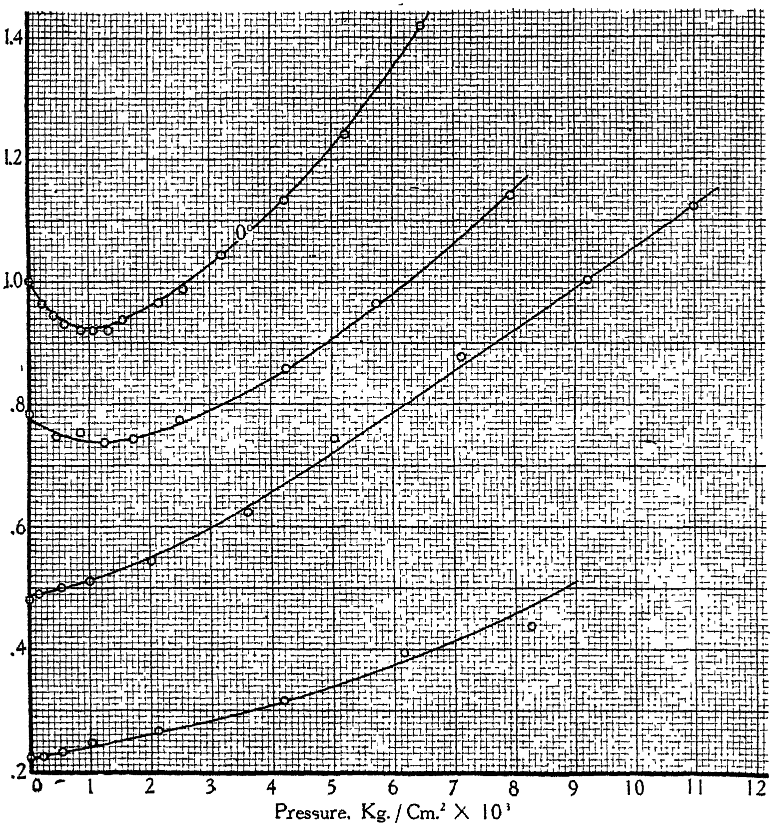

FIGURE 5. The relative viscosity of water at 0°, 10°, 30°, and 75° as a function of pressure.

i-Butyl Alcohol. Two fillings were necessary, the connecting pipe to the pressure generating apparatus having split on the first application of 10000 kg. at 30°. The second filling gave all the points at 75°, and the points at 10000 and 12000 at 30°, and several check points at lower pressures, which agreed within 0.1%.

n-Octane. Two fillings were necessary; after a number of readings at 30°, the weight stuck because of mechanical dirt. A heavier weight was used with the second filling. The results of the two fillings agreed after correction for the difference of weight.

Ethyl Chloride. The boiling point at atmospheric pressure is about 12°. The experiment was done in winter; during the filling of the apparatus the room was cooled to 0° C. by opening the windows.

Acetone. This was cleaned from mechanical dirt before filling the apparatus by filtering through glass wool.

Ethyl Ether. Two fillings of the apparatus was necessary, the weight sticking because of mechanical dirt after the run at 30°. A check reading was made at 30° with the second filling, agreeing within a few thousandths of a second.

Nitro Benzene. Readings were obtained only at 30°. At 75°, at 1200 kg., the liquid short circuited, as it did also at 2200. The apparatus was then taken apart, and the nitro benzene found completely decomposed, with a heavy deposit of lamp black.

Incidental Data.

In addition to the viscosity, a certain amount of incidental data was also obtained, as already mentioned. The approximate values of the freezing pressures are collected in Table VII.

The compressibility of glycerine was also determined approximately. This was done by a new method, which is to be applied in the future to a large number of liquids, and will be described in detail then. Briefly, the liquid is placed in a piezometer with freely moving piston, and immersed in the liquid by which pressure is transmitted. Under pressure, the piston moves in, equalizing pressure inside and out, and the motion of the piston is measured by a sliding wire scheme with potentiometer contacts much like the lever arrangement for measuring compressibility. Since the compressibility of glycerine was needed only in a correction term, no attempt was made to apply all the corrections in working up the results, and in Table VIII the change of volume at 30° is tabulated as a function of pressure to only two significant figures. The particular interest of this substance, glycerine, lies in its extremely low compressibility for a non-metallic substance.

Comparison with Previous Results.

For comparison there are practically only the results of Faust[1] to 3000 kg. on ethyl alcohol, ether, and CS_2. He finds for ethyl

alcohol an increase of viscosity at 30° under 3000 kg. of 2.94 fold against my 2.31, for ether 3.96 fold against my 3.27, and for CS_2 3.43 against 2.03. The agreement certainly ought to be much closer. Faust used a flow method through a glass capillary under a varying head of mercury. It is not evident from his paper whether all the corrections were applied, but it is hard to see how any corrections could be responsible for so large a difference.

TABLE VII.

ROUGH FREEZING DATA UNDER PRESSURE.

Substance	Freezing Data 30°	Freezing Data 75°
n-hexane	10600 kg./cm.^{2}	
n-octane	6100	10000
i-amyl Decane	Freezes between 4000 and 6100	Melts between 8200 and 7130
Ethylene Dibromide	Freezes between 600 and 800	Freezes between 2500 and 2800
Cineole	Freezes between 900 and 1000	Freezes between 2100 and 2500
Oleic Acid	Freezes between 100 and 1600	Melts below 5000
n-amyl ether	Freezes between 8200 and 9500	
Cyclohexane	Freezes between 400 and 500	Freezes between 1400 and 1600
Methyl Cyclohexane	Freezes between 8000 and 10000	
Diethyl Aniline	Melts between 3000 and 2600	Freezes between 7200 and 7800
o-xylene	2400	5500
m-xylene	4000	above 5200
p-xylene	490	1900

GENERAL CHARACTER OF THE RESULTS.

In certain qualitative features, the behavior of all the liquids investigated here, except water, is alike, although there are very large quantitative differences. The viscosity increases with pressure at a rapidly increasing rate, so that if viscosity is plotted against pressure a curve of very rapid upward curvature is obtained. This is unusual;

TABLE VIII.

COMPRESSIBILITY OF GLYCERINE.

Pressure kg /cm.²	$\frac{\Delta V}{V_0}$ at 30°	Pressure kg./cm.²	$\frac{\Delta V}{V_0}$ at 30°
2000	.042	8000	.107
4000	.068	10000	.121
6000	089	12000	.134

most pressure effects become relatively less at high pressure by a sort of law of diminishing returns. In Figure 6 is shown viscosity against

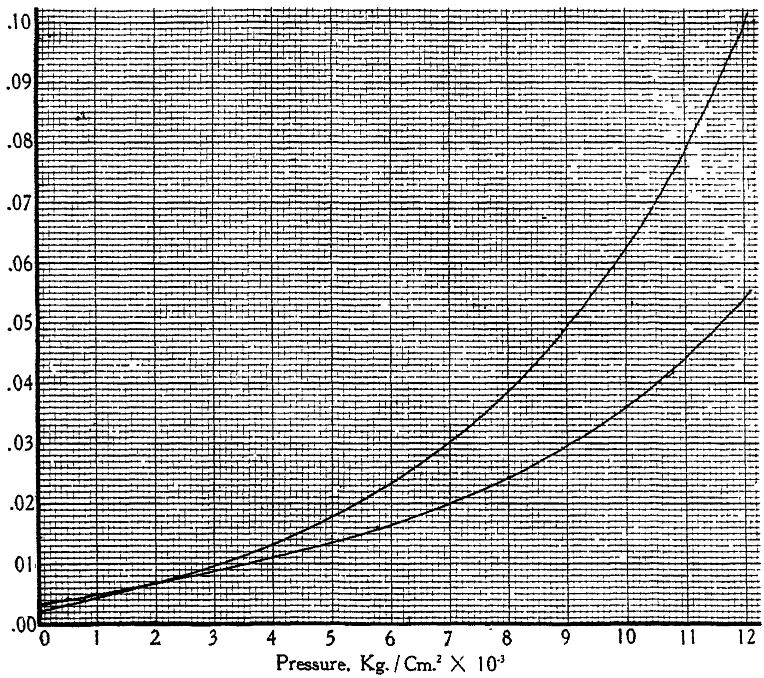

FIGURE 6. The viscosity in Abs C.G.S. units at 30° C. of CS_2 and ether as a function of pressure. The curve for ether starts below that for CS_2 and rises above it beyond 2000 kg.

pressure at 30° for CS_2 and ether, two substances with comparatively small pressure effect. It is seen that over the first two or three thou-

sand kilograms the relation between pressure and viscosity is nearly linear, but above this the departure is extreme. If logarithm viscosity is plotted against pressure a curve is obtained in general concave toward the pressure axis. The curvature is much the greatest at low pressures; above 2000 or 3000 kg. the curve approximates to a straight line, or indeed in a number of cases reverses curvature. This means that above 3000 viscosity increases approximately geometrically as pressure increases arithmetically.

A number of substances show reverse curvature, log viscosity being convex toward the pressure axis at high pressures, which means that viscosity increases more rapidly than geometrically when pressure increases arithmetically. Eugenol and p-cymene show the effect more markedly than do any other substances. The following list

TABLE IX.

LIST OF SUBSTANCES FOR WHICH LOG η IS CONVEX TO PRESSURE AXIS AT HIGH PRESSURES.

Substance	Temperature	
i-propyl Alcohol	30°	
i-butyl Alcohol	30°	
i-amyl Alcohol	30°	
i-pentane	30°	75°
Ethyl Acetate	30°	
n-butyl Bromide	30°	75°
Chloroform		75°
CS_2	30°	75°
Methyl Cyclohexane	30°	75°
Chlorobenzene		75°
Diethyl Aniline		75°
Toluene	30°	75°
o-xylene		75°
m-xylene	30°	75°
p-cymene	30°	75°
Eugenol	30°	75°
Petroleum Ether	30°	

contains those substances for which this effect seems certain beyond experimental error.

The temperature coefficient of viscosity is shown by the rows in Table V. giving η_{30}/η_{75}. Here again the effect is abnormal; most

temperature effects become less at high pressures, which is to be expected if the modification in the structure produced by temperature agitation becomes less under the greater constraints imposed by the high pressure. But here the relative change of viscosity with temperature becomes very markedly greater at high pressure, the ratio η_{30}/η_{75} changing under 12000 kg. by a factor of as much as 4.

Apart from these qualitative resemblances, the most varied quantitative behavior is shown by the various substances. In fact, viscosity is a unique property in regard to the magnitude of the pressure effect and its variation from substance to substance. The compressibility at atmospheric pressure, for example, varies by a factor of not more than four or five fold for the substances investigated here, and under 12000 kg. the compressibility of any one substance diminishes by not over 15 fold. The thermal expansion changes by a factor of two or three under 12000 for these liquids, and the specific heats and thermal conductivities do not vary more. Excepting water, the smallest effect of pressure on viscosity found above is that on methyl alcohol, which increases 10 fold under 12000, and the largest is by over 10^7 for eugenol (obtained by linear extrapolation, which gives too low a value).

In general the largest pressure effects are for those substances with the most complicated molecules. This is very plainly shown by the series of the alcohols, or by the various compounds derived from benzene; the relative pressure effect is greater the more complicated the group substituted for hydrogen. There is also a very marked constitutive effect, the iso-compounds having a larger effect than the normal compounds, and a similar effect is seen in the three xylenes. A heavier atom substituted into a molecule produces in general a larger pressure effect, as is shown in the series C_2H_5Cl, —Br, —I. or by chloro- and bromo-benzene. There appears, however, to be a tendency working in the other direction at low pressures. In the ethyl halogen series, the increase of viscosity produced by 500 kg. is in the order Cl, Br, I, whereas the increase under 12000 is in the order I, Br, Cl. It may well be that the abnormal effect at low pressure is due to the abnormally large compressibility of C_2H_5Cl, due to the neighborhood of the critical point, at which the compressibility is infinite. Abnormal behavior is also shown by methyl cyclohexane, the pressure effect being larger than for cyclohexane.

Water is quite different in character from the other liquids. Previous investigations have been made to 400 kg. by Hauser.[1] He

found that, below 30°, viscosity decreases with increasing pressure, and above 30°, increases. At higher pressures we now find that at 0° and 10° there is a minimum viscosity, at a pressure roughly 1000 kg., the minimum being less pronounced at 10° than at 0°. At 30° and 75° there is a regular increase of viscosity with pressure over the entire range. (Not much weight must be placed on the precise numerical values given for 75°, there being much experimental uncertainty here because of electrical conductivity by the water.) It is natural to see in this abnormal behavior of water an association effect; at low pressures and temperatures, water is strongly associated with large molecules and a large viscosity, but as pressure increases the association decreases, and the average size of the molecules decreases, giving a term in the viscosity which diminishes fast enough to more than compensate the normal increase of viscosity under pressure. At higher pressures the association effect is exhausted, and the behavior becomes normal.

Theoretical Discussion.

It is generally recognized that the mechanism of viscosity is very different in a gas and a liquid. In a gas, viscosity increases with rising temperature, and is constant with increasing pressure, whereas in a liquid, viscosity decreases with rising temperature and increases with rising pressure. A further essential difference is shown by the connection between viscosity and thermal conductivity. In a gas, momentum and energy are conveyed by the same mechanism, so that reciprocal viscosity and thermal conductivity are proportional, whereas in a liquid the mechanisms are different, as is shown by the increase of thermal conductivity with increasing pressure and the very great decrease of reciprocal viscosity.

The mechanism of viscosity and thermal conductivity is well understood for a gas, but we have little understanding of the mechanism for a liquid, and there have been few attempts at theoretical explanation. In the following I shall not attempt to offer a theory of liquid viscosity, but shall try to show that the pressure phenomena make it pretty evident that there is a very important element in liquid viscosity which has been overlooked in previous theoretical attempts.

The few theoretical discussions of liquid viscosity have attached especial significance to the relation between viscosity and volume. Faust[1] drew from his measurements the conclusion that at high pressures viscosity tends to a limiting behavior, in which it is a linear

function of the volume only, so that the viscosity is constant at a given volume independent of temperature (pressure varying). This behavior he found for CS_2 and ether in the pressure range of 3000 kg., but he found that ethyl alcohol did not approach such a behavior. The new data of this paper show that at high pressures the viscosity of all substances departs very far indeed from being a linear function of volume at a definite temperature, or from being a pure volume function of any kind. Faust saw a connection between the supposed linear relation between volume and viscosity and Tammann's theory that in the domain of high pressures the forces of molecular attraction are constant.

The most elaborate of the theories of liquid viscosity is that of L. Brillouin,[8] whose guiding idea is that part of the viscosity arises from a transfer of momentum through the liquid by elastic waves, in much the same way as Debye has a thermal conduction (energy transfer) by elastic waves. The mathematical working out of the idea is elaborate and reference must be made to the original paper; the important result is found that the dissipation of the continuity of the waves by temperature agitation produces a viscosity decreasing with rising temperature. No formula is given for the effect of pressure on viscosity at constant temperature, and indeed the theory must be extended to be capable of giving such a formula, but an exact expression is found for the change of viscosity with temperature at constant volume. The expression is:

$$\left(\frac{\partial \eta}{\partial \tau}\right)_v = -\frac{5}{3}\frac{\chi}{V^2},$$

where χ is the thermal conductivity in absolute mechanical units and V is the velocity of sound. The value for the temperature coefficient of viscosity at constant volume given by the formula turns out to be about 100 times smaller than the coefficient as ordinarily measured at constant pressure (atmospheric). Brillouin tried to get an exact numerical check of his expression for $(\partial\eta/\partial\tau)_v$ from the data of Faust, and drew the conclusion that there was agreement within experimental error, which, however, he admitted might be very large.

The new data of this paper are sufficiently accurate to allow a check of the formula. It turns out that the formula fails by so large a factor as to constitute another order of magnitude. Thus for ether at a volume of 0.80 my value of viscosity at 30° and 75° gives

$$\left(\frac{\partial \eta}{\partial \tau}\right)_v = -.00106,$$

against a value of $(5/3)(\chi/V^2)$ of

$$2.18 \times 10^{-7}\left[=\frac{5}{3}\times\frac{1.38\times 10^4}{(3.24)^2\times 10^{10}}\right].$$

The values of χ, V, and volume involved in this calculation were taken from previous papers on compressibility and thermal conductivity.[3, 4] The difference between the calculated and observed value is so great that experimental error seems absolutely incapable of explaining it.

Another theory of viscosity has been developed by Phillips,[9] who has momentum transferred from part to part of the liquid by a quantum mechanism. He draws the conclusion that viscosity is a volume function only, so that his theory does not fit with these experiments even as well as that of Brillouin, who gives the right sign for $(\partial\eta/\partial\tau)_v$. Just how far η fails of being a pure volume function may be inferred from Figures 7 and 8, plotting log η against volume at 30° and 75° for i-amyl alcohol, ether, and CS_2. I-amyl alcohol, being associated, might be expected to be exceptional, but there is no such reason for the failure of ether and CS_2.

It seems fairly evident from the failure of the previous theories that there is some very important element in the situation not hitherto considered. This I believe to be an interlocking effect between the molecules which prevents the free motion of one layer of molecules over another. Slipping of two interlocking molecules past each other can take place only when haphazard temperature agitation has so far separated them that the interlocking parts are free. According to such a picture, viscosity would be expected to decrease with rising temperature both at constant pressure and constant volume. When the volume is decreased at constant temperature by increasing pressure, a comparatively small decrease of total volume may evidently produce a very large increase of interlocking, and the effect would be expected to increase more and more rapidly as the pressure increases. Furthermore, it is evident that the magnitude of the effect may be very different for different substances.

Such an interlocking effect would be expected to be most important in the most complicated molecules, and strong evidence in favor of such a picture is the very marked tendency found experimentally for the pressure effect to increase as the molecule becomes more complicated. In order to show this I have plotted the increase in log η produced by the first 500 kg. against a number which attempts to give

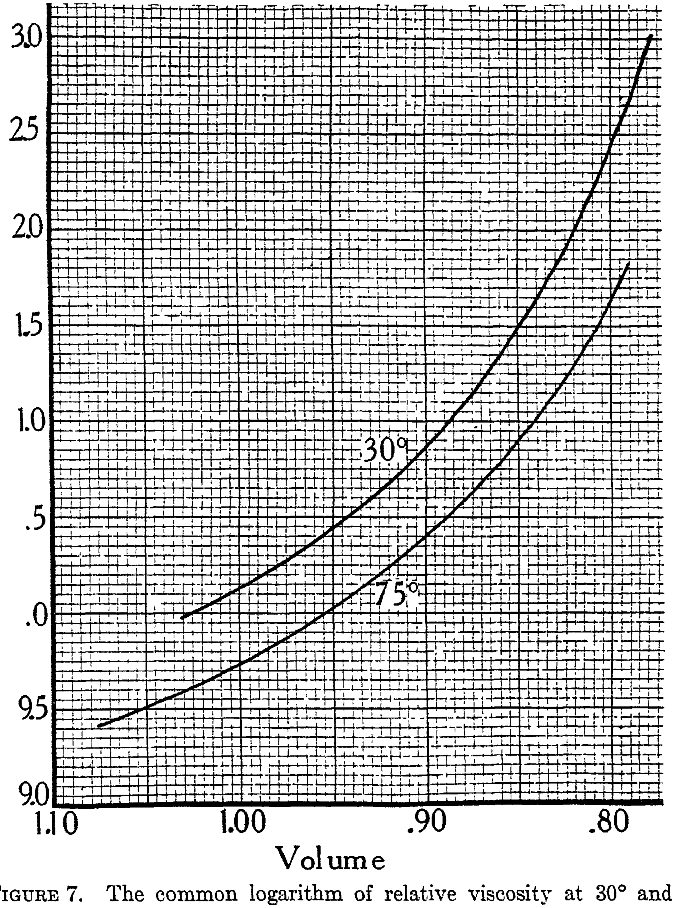

FIGURE 7. The common logarithm of relative viscosity at 30° and 75° of i-amyl alcohol as a function of volume.

some measure of the complication of the molecule. Evidently "complication of the molecule" is a very hazy concept, and any numerical measure of it can be only very crude. It is evident, I think, that the molecule may be more complicated either because it contains more atoms or because the atoms themselves are more complicated. As a measure of the complication of the atom I have taken the number of extra-nuclear electrons (the atomic number), and to measure the complication of the molecule I have multiplied the total

number of extra nuclear electrons in all the atoms which the molecule contains by the total number of atoms in the molecule. We may call such a number the "complexity number." It evidently neglects many factors which we would like to include: for example, no distinction is made between an iso- and a normal alcohol, although our ordinary structural formulas would suggest that the molecule of an iso-alcohol is more likely to interlock with others of its kind than is a molecule of a normal alcohol.

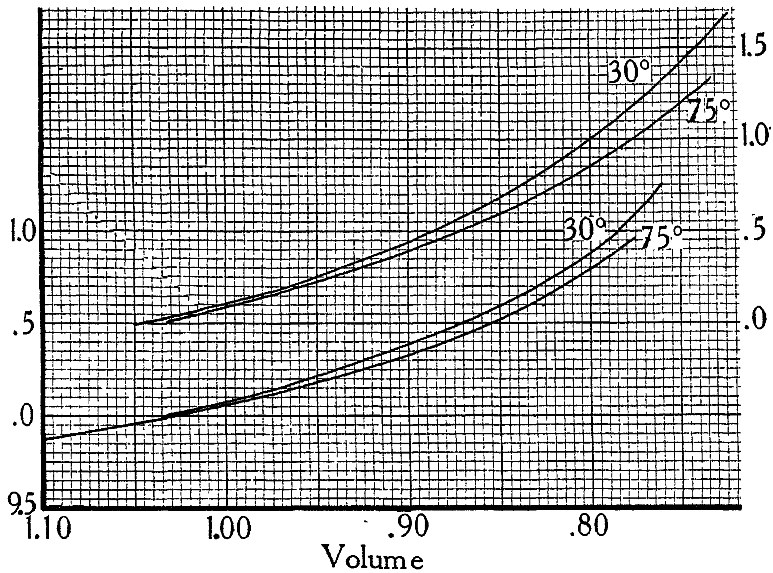

FIGURE 8. The common logarithm of relative viscosity at 30° and 75° of ether and CS_2 as a function of volume. The curves for ether are the upper curves with the scale of ordinates at the right.

In Figure 9 is plotted the effect of 500 kg. on log η against the logarithm of the complexity number. It is evident that there is a correlation which is perhaps as close as could be expected when the extremely arbitrary character of the complexity number is considered and the arbitrariness of comparing the pressure effect for all liquids at the same temperature, 30°, and at low pressures. It must be admitted that the correlation coefficient shown by the figure is not very high, but it will appear more significant if one will take the trouble to

make similar plots against other properties which might be significant. I have not been able to find any other properties of the liquid which show nearly as close a correlation as the complexity number. For instance it has been suspected by some that viscosity in a liquid is due to the attraction between the molecules, which are prevented from moving freely with respect to each other by the attractive forces. If the molecular latent heat of vaporization is taken as a measure of the attractive force, and log η is plotted against it, no correlation whatever will be found. Or one might expect a correlation between absolute viscosity at atmospheric pressure and the pressure effect, but on plotting these two against each other much less correlation will be found than with the complexity number.

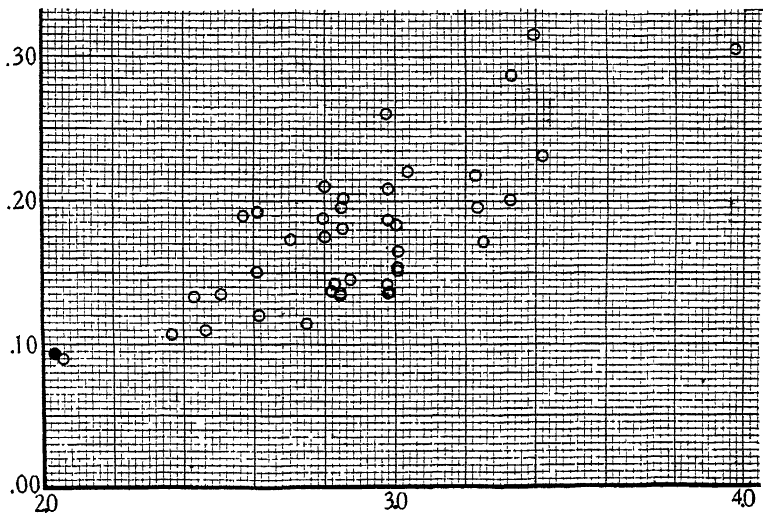

FIGURE 9. The common logarithm of the ratio of the viscosity at 500 kg. to that at atmospheric pressure at 30° C. of all the substances of this paper (except water) plotted as ordinates against the common logarithm of the "complexity number." The complexity number is defined as the product of the number of atoms in the molecule by the number of all the extra-nuclear electrons of the molecule.

If the correlation shown in the figure does not seem sufficiently real, perhaps still stronger evidence of the importance of molecular complexity may be found by confining oneself to a single related series of chemical compounds and noticing the effect of making the molecule

more complicated in the series. Striking examples of this are the increase of pressure effect with molecular weight in the series of alcohols, or of hydrocarbons C_nH_{2n+2}, or the ethyl halogens.

If some such interlocking effect as suggested above is an important part of the viscosity mechanism, this means that so far as viscosity phenomena are concerned the molecule preserves its inviolability and continues to function as a unit when the volume is greatly decreased by high pressure. There are other phenomena, such as compressibility, in which the molecule seems to lose its significance at small volumes, and the atom becomes more significant. A reason for the difference may be seen in the different sorts of relative motion involved. If a molecule ceased to function as a whole during viscous shear it would be torn apart by the relative motion of the parts of the liquid, but the relative motion involved in a hydrostatic compression is not such as to destroy the molecule, even under comparatively large changes of volume.

Summary.

A method has been devised for the measurement of the viscosity of liquids under pressure and applied to 43 pure liquids up to a pressure of 12000 kg./cm.^{2} at 30° and 75° C.

Viscosity increases rapidly with increasing pressure; at low pressures the relation between viscosity and pressure is approximately linear, but at higher pressures viscosity increases much more rapidly. The effect of 12000 kg. may vary from 10 fold to 10^7 fold (excepting water). Log viscosity against pressure is at first concave toward the pressure axis, but above 3000 becomes nearly straight, and for a number of liquids even becomes convex toward the pressure axis. The temperature coefficient of viscosity increases under 12000 kg. by a factor of several fold, varying much with the liquid. Water is exceptional; at low temperature its viscosity decreases with rising pressure, but there is a minimum at about 1000 kg., and from here on the viscosity increases. At higher temperatures its viscosity increases at all pressures, but the increase is very much less than for any of the other liquids measured.

Incidentally a number of new freezing points have been determined under pressure, and the pressure-volume relation for glycerine roughly measured.

No theory proposed hitherto is adequate to account for these pressure phenomena. It is suggested that an interlocking effect between the molecules is an important element in the situation, an idea which

is supported by the rapid increase of the pressure effect as the molecule becomes more complicated.

It is a pleasure to acknowledge the assistance given by my mechanic Mr. E. T. Richardson in setting up the apparatus and making many of the readings.

THE JEFFERSON PHYSICAL LABORATORY,
Harvard University, Cambridge, Mass.

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BOILING POINTS OF LIQUIDS FROM EASTMAN KODAK CO.,
SEE PAGE 73

n-propyl alcohol	96–98 C.
i-butyl alcohol	106–108
i-amyl alcohol	130–132
n-hexane	68–69
n-octane	124–126
i-amyl-decane	156–158
Ethyl chloride	12 5–13
Ethyl bromide	38–40
Ethyl iodide	71–72
Acetone	55.5–55 8
Cineole	53–54 at 8 mm.
Oleic Acid	U.S.P.
Aniline	mpt. —6
Diethyl aniline	102–104 at 10 mm.
Nitro benzene	mpt. 5
O-xylene	143.5–144.5
m-xylene	138–139
p-cymene	176.5–177.5
Eugenol	135–140 at 15 mm.

Proceedings of the American Academy of Arts and Sciences.

Vol. 61. No. 4. February, 1926.

THERMAL CONDUCTIVITY AND THERMAL E.M.F. OF SINGLE CRYSTALS OF SEVERAL NON-CUBIC METALS.

By P. W. Bridgman.

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Presented October 14, 1925. Received November 16, 1925.

TABLE OF CONTENTS.

Introduction.

In this paper previous investigations of the properties of several metals crystallizing in non-cubic systems[1] are extended to thermal conductivity and thermal e.m.f. The thermal conductivity is measured at room temperature and the thermal e.m.f. in the range between room temperature and 100° C. Fairly complete results are presented here for Zn, Cd, and Sn in all possible orientations in the crystal and for Bi over a restricted range of orientations, whereas for Sb and Te only measurements of thermal e.m.f. have been obtained and only for those orientations in which the cleavage plane is nearly parallel to the length. The mechanical difficulty of obtaining suitable specimens of the proper orientations is responsible for the lack of completeness.

Apart from the exact numerical results, there are several interesting questions involved in the data presented here. With regard to thermal conductivity we have to ask whether the symmetry relations deduced by Voigt hold, and also whether the Wiedemann-Franz proportionality between electrical resistance and thermal conductivity holds in detail for all directions in the crystal. It will appear that the symmetry relations of Voigt do hold, but that the Wiedemann-Franz ratio does not hold in detail. With regard to the thermo-electric effects, we have to discuss the Thomson heat and the Peltier heat. It will appear that the analysis of Voigt considers only the Thomson heat, the Peltier heat at surfaces of discontinuity, which is numerically by far the more important effect, having been completely neglected. It is probable that the symmetry relations of Voigt apply to the Thomson heat, but that the symmetry relations of the Peltier heat are different. It is shown in the discussion that a Peltier heat varying with the orientation in the crystal involves an internal Peltier heat when the direction of current flow in the crystal changes.

Part I. Thermal Conductivity.

Method of Measuring Thermal Conductivity.

The methods available were much restricted by the requirement that the parts of the crystal subjected to measurement should not be subjected to any machining operation. Previous work with single crystals[1] has shown the very great difficulty of machining without seriously upsetting the crystal structure. The general scheme of the method adopted was as direct as possible; the temperature difference between two points at a known distance apart on a rod was measured when a known heat current passes along the rod. The heat current was produced electrically by a heating coil attached to one end of the rod, the other end of the rod being maintained at constant temperature in a temperature bath and so acting as a sink. The temperature difference was measured by a differential thermo-couple attached to the rod at intermediate points.

The experimental arrangements for measuring the thermal conductivity are shown in Figure 1. The metal is a unicrystalline casting, *A*, made by methods already fully described,[2] about 10 cm. long and very nearly 6 mm. in diameter. It is mounted by soldering with low melting solder into the massive copper block *B*. A special jig used during the setting of the solder ensured that the rod was central in the block. The heating coil *C* at the upper end was contained in a

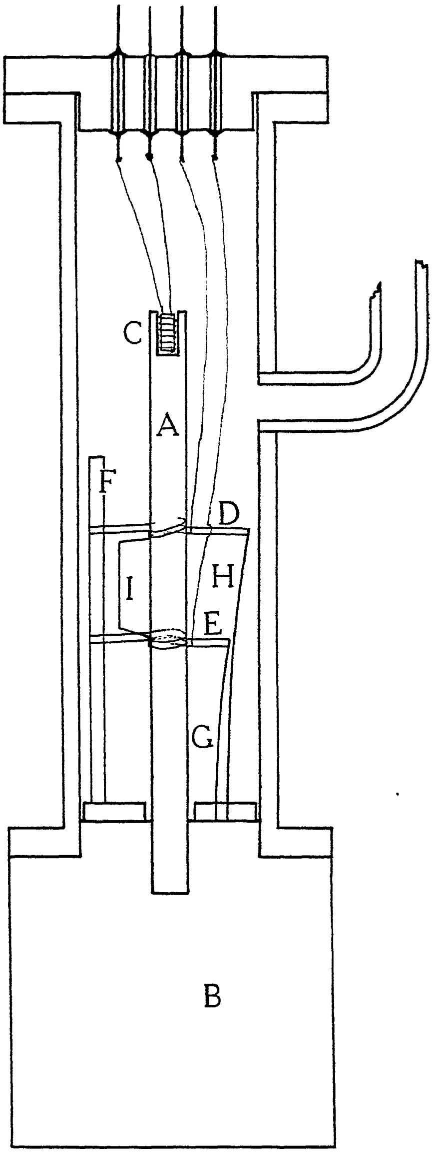

Figure 1. Section of apparatus for measuring thermal conductivity.

recess, 3.3 mm. in diameter and 6 mm. deep, drilled into the rod. Any damage to the crystal structure in drilling the hole was confined to the immediate neighborhood of the hole, and could not affect the lines of heat flow near the thermo-couples. The heating coil was of high resistance wire 0.009 cm. in diameter, wound in a thread cut in a miniature cylinder of pipestone, the total resistance being about 35 ohms. The coil was insulated externally with a wrapping of paper 0.0025 cm. thick; before an experiment the insulation resistance between coil and rod was checked and required to be over 10^8 ohms. The leads to the heating coil were of copper 0.013 cm. in diameter. To insure good thermal contact between coil and rod the hole in the upper end of the rod was filled with vaseline before inserting the coil, and the excess vaseline was afterward wiped away.

The thermo-couple was of copper-constantan ribbon, made by rolling to a thickness of less than 0.0025 cm. wire originally 0.015 cm. thick. The couple was held in contact with the rod with springs. The details of construction of the couple were as follows: Two ribbons of copper, D and E, attached at one end by soldered loops to the insulating pillar F, were passed once around the rod, and at the other ends were held taut by the piano wire springs G and H from which they were insulated by glass sleeves. Underneath the two loops of copper was passed the constantan ribbon I, which was then soldered to the copper with the minimum amount of solder. As shown in the figure, the constantan ribbon was bent at right angles to the rod where it made contact with the copper. Copper connections 0.012 cm. in diameter, soldered to the ribbons D and E near the rod, led to a potentiometer and provided means of measuring the potential difference and so the difference of temperature between the two ends of the constantan ribbon. The thermo-couple was insulated from the rod by a single wrapping of oiled paper 0.0025 cm. thick, stuck to the rod with a very thin coating of air drying lacquer. The insulation resistance between couple and rod was always required to be greater than 10^8 ohms. To ensure better thermal contact between rod and couple the loop around the rod was painted with lacquer above the paper after assembling. The distance between the junctions constantan to copper was read for each specimen with a telescope mounted on a comparator, and was always nearly 2 cm.

The springs holding the thermo-couple taut were so mounted that they could be slacked after a run, and the crystal rod slipped out through the loosened loops. The couple could conversely be slipped over a freshly mounted rod and the loops tightened into place. Simi-

larly the heating coil at the upper end was removable from specimen to specimen. All the measurements on thermal conductivity on all the specimens were made with the same thermo-couple and same heating coil, and for all except Bi with the same heat input, so that all the results are comparable, apart from any question of absolute values.

The rod with the thermo-couple attached was placed inside a brass cylinder 3 cm. in inside diameter and 20 cm. long. This cylinder was provided with flanges at the top and bottom by which vacuum tight connection was made to the copper block *B* and to a brass plate at the upper end through which passed terminals for the thermocouple and the heating coil insulated with glass tubing and deKhotinski cement. Connection to the vacuum pump was made with a brass tube soldered into the side of the cylinder. The vacuum was produced with a mercury diffusion pump with the conventional forepumps. There was provision for a liquid air trap, but this was never used. Trial showed no difference in the results when the trap was packed in ice or when left at room temperature. Since this difference of temperature corresponds to a difference of vapor pressure of the mercury of about eight fold, it was concluded that the heat dissipated by convection or conduction by the gas surrounding the rod was negligible, and that the diffusion pump vacuum at ordinary temperatures was sufficient. The importance of the vacuum became at once obvious if one attempted readings at full atmospheric pressure. Here there were fluctuations so violent that no consistent readings could be obtained; what rough readings could be obtained indicated a conductivity materially higher than given with the vacuum, showing that an appreciable part of the heat input was carried away by the gas at atmospheric pressure.

The electrical measurements do not need detailed description The thermal e.m.f. of the couple and the heating current were both measured with the same potentiometer that was previously used in measuring the effect of pressure on the thermal conductivity of metals,[3] and a full description will be found in that paper. The heating current was provided by a storage battery of 12 volts in series with appropriate resistances and a ballast lamp to maintain constancy. The maximum heating current was about 0.4 amp. The sensitiveness of the measurements was very much better than 0.1%, and very much better than the consistency of the measurements with different specimens.

The experimental procedure was as follows: The rod was soldered into the copper block *B*, paper strips 6 mm. wide were lacquered on at

the mean position of the thermo-couples, the thermo-couples adjusted, the heating coil inserted, soldered connection made between the couple and the heating coil leads and the fixed copper terminals in the upper brass plate, clamps applied to the flanges to make them vacuum tight (the conventional vacuum wax was used underneath the flanges), the assembly was then placed in the temperature bath of water at room temperature with the upper brass plate projecting a couple of cm. above the surface of the water, connections were made to the vacuum pump through a conical joint between glass and brass sealed in deKhotinski cement (the diffusion pump and the brass assembly were slung from counterpoised arms to allow free relative motion), the insulation resistance was tested between the thermo-couple and the heating coil and the grounded rod, soldered connection made between the outer terminals in the upper brass plate and the potentiometer and the source of heating current, and the vacuum pump and heating current started. The vacuum was tested by noting the character of the discharge through a small discharge tube excited by a transformer on the commercial 60 cycle 110 volt circuit. No final readings were made until ½ hour had elapsed after the last previous change of heating current, this interval having been proved sufficient by trial, and after reaching a vacuum so high that all discharge had ceased. Readings were made for two different heat inputs, one about 4 times the other; the readings with the smaller heat input were made first and were merely by way of check. These were sometimes made before complete equilibrium was reached. In general the conductivity calculated from the small heat input was a few per cent higher than that with the larger input; the results with the larger input are to be preferred, and are the only ones retained in the final results.

Detailed Results.

The theoretical connection between thermal conductivity and direction in the crystal has been worked out by Voigt; the connection is the same as for the electrical conductivity. This means that for the crystals investigated here, which have rotational symmetry, the behavior of the conductivity in all directions is completely characterized by two constants. These two constants are the thermal conductivity parallel and perpendicular to the axis of rotational symmetry. Denote these conductivities by κ_{11} and $\kappa_{\perp}$, and introduce the reciprocal conductivity or thermal resistance, namely

$$\lambda_{11} = \frac{1}{\kappa_{11}}, \quad \text{and} \quad \lambda_{\perp} = \frac{1}{\kappa_{\perp}}.$$

The relation of Voigt is now

$$\lambda_\theta = \lambda_\perp + (\lambda_{11} - \lambda_\perp) \cos^2 \theta,$$

where λ_θ denotes the reciprocal conductivity in the direction inclined at the angle θ to the axis. The relation for electrical resistance is the same, namely

$$\rho_\theta = \rho_\perp + (\rho_{11} - \rho_\perp) \cos^2 \theta.$$

Now eliminate θ between the equations, giving

$$\lambda_\theta = \frac{\rho_\theta(\lambda_{11} - \lambda_\perp) + \rho_{11}\lambda_\perp - \rho_\perp\lambda_{11}}{\rho_{11} - \rho_\perp}.$$

Hence λ_θ is a linear function of ρ_θ, in virtue merely of the symmetry relations, and without any special hypothesis connecting electrical and thermal conductivity.

One of the points of chief interest in this investigation of thermal conductivity is whether the Wiedemann-Franz ratio continues to hold for the individual directions in a crystal. If this is the case, λ in any direction is proportional to ρ in that direction, which is at once seen to be consistent with the equation above, for on putting $\lambda_{11} = x\rho_{11}$, and $\lambda_\perp = x\rho_\perp$, the equation collapses to

$$\lambda_\theta = x\rho_\theta.$$

Hence if the Wiedemann-Franz ratio holds for all directions, not only is λ_θ a linear function of ρ_θ, but the straight line passes through the origin. In the following this criterion is applied graphically to the thermal resistance.

In computing the results, the data needed are the heat input, given by the heating current and resistance of the heating coil, the temperature difference, given by the thermal e.m.f. of the couple and the constant of the couple, the cross section of the rod, and the distance between the junctions of the thermo-couple. In terms of all these data the absolute thermal conductivity can be at once obtained, provided that heat losses be neglected. The heat losses are of two kinds; losses by radiation or by convection and conduction through the small amount of gas remaining, and loss by conduction along the leads of the heating coil or an effective loss by conduction along the wires of the thermo-couple. The precise amount of these various losses would be difficult to determine experimentally; calculation shows most of them to be very small, and direct experiment by varying the gas pressure showed that loss through the gas must be small. In the calculation of conductivity such losses were entirely neglected,

and it must be recognized that there is here a possible source of error. The heating was so small that the rise of temperature above the surroundings at the heating coil end of the rod was only 2° for Sn, less for Zn and Cd, and not over 7.5° in the extreme case of Bi. The heat loss should be proportional to the temperature rise and therefore inversely proportional to the thermal conductivity. There is another possible source of error in the value of the constant assumed for the thermo-couple. It would have been difficult to calibrate the couple directly, and the value (100×10^{-6} volts = 2.48° C.) given by L. H. Adams[4] in his Table for copper—"Ideal" was assumed. It is questionable, however, whether the very great mechanical deformation involved in rolling the wire flat (it was not annealed afterward) may not have seriously affected the constant. However, since all specimens were measured with the same couple, any error in the constant can produce no error in the relative conductivities of the various samples, and can have no effect on any conclusions made as to connections between electrical and thermal conductivity. The absolute thermal conductivities calculated, neglecting heat losses and with the assumed value for the thermo-couple constant, are uniformly too high to be consistent with the values given in the literature for cast rods in which the crystal grains are at haphazard. The inconsistency amounts to about 20% for Cd, Zn, and Sn, and for Bi to about two fold. I do not believe that nearly all of this discrepancy can be due to the factors discussed (heat leak and constant of the couple) but that an important part must be real, which means that the thermal conductivity in my single crystals is high, arising perhaps from a combination of unusual purity with a perfectly regular atomic arrangement. It is to be expected that this effect will be particularly large in Bi, in which the crystalline character is most pronounced, and cleavage most easy.

The Specimens. The rods were cast and examined to ensure that they contained only one crystal grain by methods already described.[1] A simple method of controlling the orientation of the crystalline axis with respect to the axis of the rod has not yet been developed, and I did as before, selecting those best oriented from a number of castings. Because of the small diameter of the casting, only 6 mm., large angles of inclination between the axis of the crystal and the casting were more common than in the larger size castings.

Zinc was Kahlbaum's best; measurements were made on 8 rods, of angles varying from 86.5° to 33°. The angle was determined from the position of the cleavage plane.

Bismuth was electrolytic metal from the U. S. Metals Refining Co., the same as the Bi of the previous measurements. Before casting into the 6 mm. rods it had been cast by the regular procedure for making unicrystalline castings into rods 2.5 cm. in diameter. These were not one grain. The lower part of these rods, which thus had experienced an additional purification, was used for the 6 mm. rods. In the previous paper it was mentioned that it is particularly hard to get Bi in unicrystalline rods, there being a very strong tendency to form several grains of very nearly the same orientation. This difficulty was again found in high degree, and in many trials only a few satisfactory rods, of angles varying from 90° to 68.5° were obtained. Since these measurements were completed, however, a much better method has been developed for obtaining unicrystalline rods of Bi. The difficulty is apparently connected with the expansion on solidifying. The crystal that separates in the bottom of the container is lighter than the liquid and is therefore mechanically unstable. Portions of the crystal tend to detach themselves after being laid down, and act as new centers of crystallization. This tendency may in large part be avoided by drawing the mold up through the top of the furnace instead of lowering through the bottom, so that the Bi crystal is in a mechanically stable position at the top.

The angle between the axis of the casting and the crystal for these Bi rods was determined from the cleavage plane.

Cadmium was Kahlbaum's best; successful measurements were made on 9 rods. The singleness of the castings was determined in the regular way by the appearance of the castings in reflected light. There was a difficulty not met before, however, in determining from the reflection pattern the location of the crystal axis, since for some reason under these special conditions not all the faces of the reflection pattern were developed. It turned out to be much simpler to obtain the location of the axis from measurement of the specific electrical resistance, the specific resistance parallel to and perpendicular to the axis having been previously determined. In measuring the resistance the apparatus of the previous paper was used. The values found for the specfic resistance varied from 6.92×10^{-6} to 8.31, the previous values for $\rho_{\perp}$ and ρ_{11} being respectively 6.80 and 8.30. It thus appears that the 9 rods used ranged through nearly all the possible orientations.

Tin was measured in 5 specimens; 3 of these were Bureau of Standards melting point samples, and 2 were Kahlbaum's purest. Again, although the reflection patterns were sufficiently developed to determine the uniqueness of the grains, all the faces were not present, so

that the orientation of the axis had to be determined from the specific electrical resistance. This ranged from 9.92×10^{-6} to 13.20; the previous values are $\rho_{\perp} = 9.9$, $\rho_{11} = 14.3 \times 10^{-6}$, so that about two-thirds of the total possible range of orientations is here represented.

Numerical Results. The accuracy of the results is so low that graphical representation is adequate. In Figure 2 is plotted for all

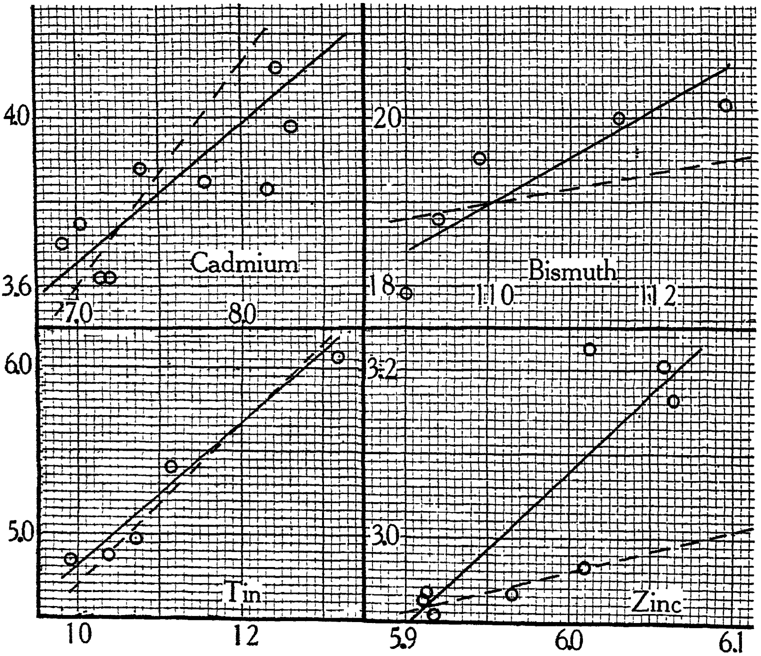

FIGURE 2. Reciprocal of thermal conductivity (ordinate) against specific resistance $\times 10^6$ (abscissa).

the metals the reciprocal of thermal conductivity (calculated as explained) against specific electrical resistance of the same sample. According to the symmetry relations developed by Voigt[5] the relation between these two should be linear. The heavy lines in the diagrams appear to be the best straight lines connecting the observed points. The experimental error is seen to be considerable. If, further, the Wiedemann-Franz ratio holds for the individual directions in a crystal, the straight line should pass through the origin. The dotted lines in the diagrams are the best lines drawn through the origin.

In the case of Sn and perhaps in that of Bi, this line connecting with the origin may also within experimental error be the line on which the points actually lie, so that for Sn and possibly for Bi the proportionality between electrical and thermal resistance holds for different directions in a single crystal. It has already been found by Kaye and Roberts[5a] that in Bi the ratio of the thermal conductivities in the perpendicular and parallel directions is 1.39, which is to be compared with my value[1] 1.27 for the ratio of the electrical conductivities. The discrepancy is in the same direction as indicated in Fig. 2.

But with Cd and Zn there seems no room for doubt that the experimental points do not lie within experimental error on the line through the origin, so that for these metals the Wiedemann-Franz proportionality does not hold in detail for different directions in the crystal. In the case of cadmium, electrical resistance varies more with direction than thermal conductivity, and for Zinc thermal conductivity varies more than electrical resistance. It would seem that these conclusions cannot be affected by any uncertainties in the values given for the absolute conductivities.

Whether or not the Wiedemann-Franz ratio holds, it is evident that for all four metals the electrical conductivity increases in the same direction in which the thermal conductivity increases.

Part II. Thermal E.M.F.

Methods of Measuring Thermal E. M. F.

The single crystal rods on which the thermal e.m.f. measurements were made were 6 mm. in diameter and about 15 cm. long. In point of time the thermal e.m.f. measurements were made before the measurements of thermal conductivity; after the thermal e.m.f. measurements some of the rods were selected for the measurements of thermal conductivity, being cut down to 10 cm. in length. The number of specimens used was as follows. Zn, 8 thermal e.m.f. specimens were measured and all 8 were again used for thermal conductivity; Sn, 14 thermal e.m.f. specimens were used from which 5 were selected for thermal conductivity; Cd, there were 14 thermal e.m.f. specimens from which 9 were selected for thermal conductivity; Bi, there were 10 thermal e.m.f. specimens of which 5 were used for thermal conductivity; Sb, there was only 1 thermal e.m.f. specimen which was not suitable for thermal conductivity; Te, there were 3 thermal e.m.f. specimens of which none were suitable for thermal con-

ductivity. With regard to Sb and Te it is to be noticed that geometrical imperfections are not a source of inaccuracy in measurements of thermal e.m.f., whereas geometrical perfection is necessary for a good measurement of thermal conductivity.

The two ends of the specimen were maintained at different temperatures by two oil baths. These baths were contained in rectangular copper boxes placed about 2.5 cm. apart, and were provided with stuffing boxes through which ran the crystal rods, projecting about 6 cm. into the bath and 10 cm. below the surface. The stuffing boxes were carefully designed so as not to exert an appreciable mechanical stress on the rods, since a mechanical stress at the stuffing boxes, which is the region of rapid change of temperature, would introduce extraneous e.m.f.'s. Both baths were vigorously stirred. One bath was provided with an electric heater with which temperature was varied in the range between room temperature and 100° C. No regulator was used; in changing temperature a heavy heating current was used, and after the desired temperature was reached it was kept very nearly constant by adjusting the heating current to that value which experiment showed was appropriate to that particular temperature. The exact temperature of each bath was read on calibrated thermometers to 0.01°. Since temperature equilibrium was attained between the crystal rods and the bath almost immediately, the error due to drift in the bath temperature was negligible. Readings were made with both ascending and descending temperature; the usual temperatures of the hot end were: room temperature, 40°, 60°, 80°, 100°, 75°, and 55°. The cold end, at the temperature of the cold bath, started at room temperature and gradually increased by conduction through the rod until at the end of the run it was usually about 28°. In order to decrease the total time of the run, the bath was cooled for the decreasing readings by drawing out hot oil and pouring in cold. The total time of a run was about 2 hours.

The thermal e.m.f. measured was that between the crystal rod and commercial copper wire. Connections were made to the crystal rods by soft soldering to each end a copper wire 0.030 cm. in diameter. The identical copper wire was used with all the specimens so that the relative results are not affected by any peculiar properties which this particular copper wire may have had.

It is evident from the dimensions of the rods and the bath that the temperature was perfectly uniform in the neighborhood of the soldered connections, and that therefore a true measure was obtained of the thermal e.m.f. between the crystal and copper.

The thermal e.m.f. was measured by a null method on the same potentiometer which was previously used in measuring the effect of pressure on thermo-electric quality,[6] and it has already been sufficiently described in detail. The thermal e.m.f. of Bi was so large that it was measured with a Siemens and Halske millivoltmeter, which was especially calibrated for this work by a simple method with a standard cell and high resistances.

In calculating the results, the observed e.m.f.'s had to be first corrected for drift of the temperature of the cold end, reducing all readings to a cold end temperature of 20°. This was easily done graphically from the readings at room temperature, 40°, and 60°, the curvature in no case being high enough to introduce perceptible error into the correction. The corrected readings were then plotted on large scale plotting paper, and a smooth curve drawn through the points. In almost all cases the ascending and descending readings agreed within experimental error. This is an important point, and is evidence of freedom from internal changes in the crystal produced by changes of temperature, such as might occur if there were stresses at the stuffing boxes or if there were incipient cleavages. This condition has not been attained in considerable of the work previously done with Bi.

The smooth curve was in all cases within experimental error a curve of the second degree. From these curves two data were now taken, the total e.m.f. of the rod between 20° and 100° (E_0), and the deviation from a linear relation of the observed e.m.f. at the mean temperature of 60° (Δ). These two data are sufficient to determine the two constants of the second degree relation between temperature and e.m.f. For each of the metals E_0 and Δ were now plotted against a parameter determining the orientation of the rod with respect to the crystal axes. In the case of Zn and Bi this parameter was the angle between the basal plane and the length of the rod; in the cases of Sn and Cd it was the specific electrical resistance at 20° C. of the rod, which was especially measured. It has already been explained that for these samples of Sn and Cd the specific resistance gave the most reliable determination of orientation. Through the observed values of E_0 and Δ smooth curves were now passed, and from these smooth curves the values of E_0 and Δ were taken at regular intervals. From these values the corresponding values of Peltier heat and Thomson heat against copper were calculated by well known methods as follows:

The relation between total e.m.f. and temperature is of the form

$$E_{\mathrm{Cu-M}} = a(t-20) + b(t-20)^2,$$

where t is temperature in degrees Centigrade. The usual sign convention is employed; a positive E means that current flows from copper to the crystal at the hot junction. Now for the Peltier heat between the metal under investigation and copper we have the familiar thermodynamic relation

$$\begin{aligned} P_{\mathrm{Cu-M}} &= \tau \frac{dE}{d\tau} \\ &= \tau[a - 40b + 2bt] \\ &= \tau[a' + 2bt] \end{aligned}$$

where τ is absolute Centigrade temperature and $a' = a - 40b$. For the Thomson heat we have

$$\sigma_{\mathrm{M}} - \sigma_{\mathrm{Cu}} = \tau \frac{d^2E}{d\tau^2} = 2b\tau.$$

Now by definition,

$$E_0 = a \cdot 80 + b \cdot \overline{80}^2,$$

and

$$\begin{aligned} \Delta &= \frac{80}{2}[a + b \cdot 80] - [a \cdot 40 + b \cdot \overline{40}^2] \\ &= b\frac{\overline{80}^2}{4}. \end{aligned}$$

These equations, solved for a' and b give

$$a' = \frac{E_0 - 6\Delta}{80}, \qquad b = \frac{4\Delta}{\overline{80}^2}.$$

The values of a' and b calculated in this way were now plotted against the orientation parameter. For the sake of uniformity and for theoretical reasons to be described later, the orientation parameter was in all cases now chosen as the specific resistance. For Zn and Bi the specific resistances were calculated from data given in a previous paper[1] from the location of the cleavage plane. It will be noticed that except for the factor τ, a' and $2b$ are equal to $P_{\mathrm{Cu-M}}$ and $\sigma_{\mathrm{M}} - \sigma_{\mathrm{Cu}}$ at 0° C.

There now follows the detailed data for the various metals.

Detailed Data.

Zinc. The 8 samples used have already been described under the measurements of thermal conductivity. In Figure 3 are shown the observed e.m.f.'s corrected for the drift of the lower temperature for

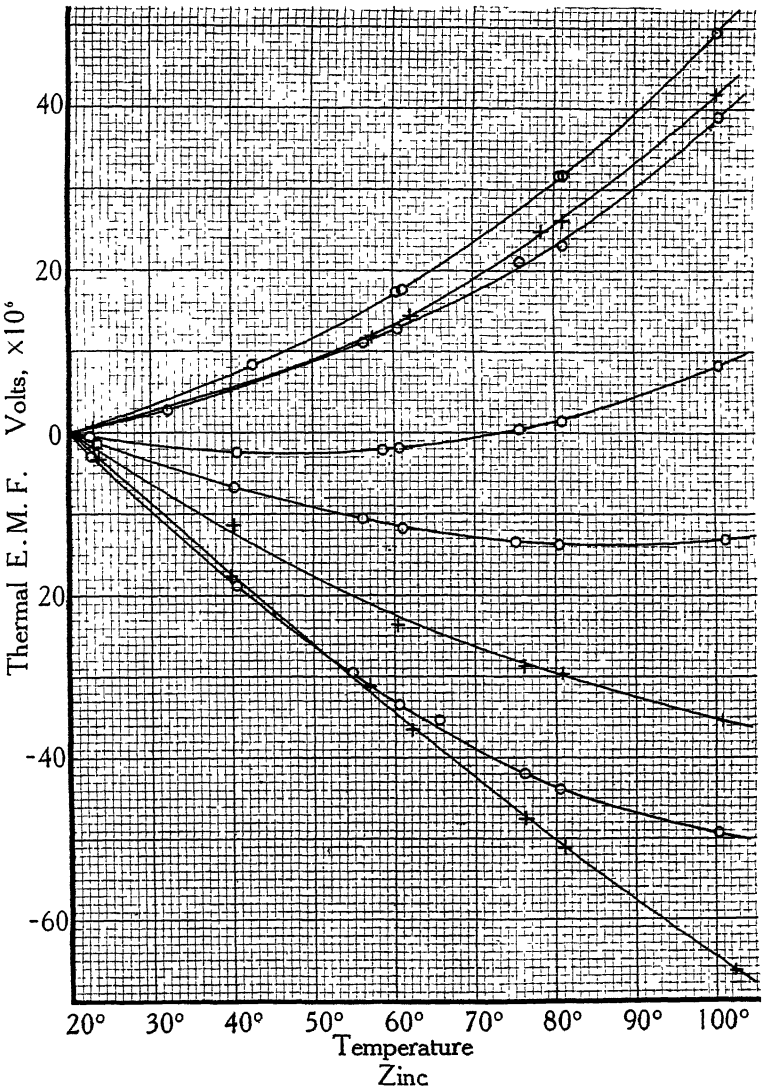

FIGURE 3. Thermal E.M.F. against copper as ordinate against temperature of the hot junction as abscissa for zinc rods of different orientations. Reading from the top down, the axis of the crystal makes the following angles with the axis of the rods: 86.5°, 83°, 80°, 60°, 57°, 48°, 46.5°, 35°.

all the specimens of zinc of various orientations. Notice that the thermal e.m.f. changes sign with the orientation. This series for Zn gives a fair idea of the experimental accuracy reached with the other metals also, and detailed data will not be given for them. The experimental curves for Zn are of the second degree within experimental error. The simplest criterion of this is that at 60° the difference between the actual curve and the straight line connecting the 20° with the 100° point is 4/3 as great as the difference at 40° and 80°. From the family of curves of Figure 3 the values of E_0 and Δ were obtained graphically, and are shown in Figure 4, plotted against the angle between the hexagonal axis and the length of the rod. In Figure 4 are also drawn the smooth curves which seemed to best

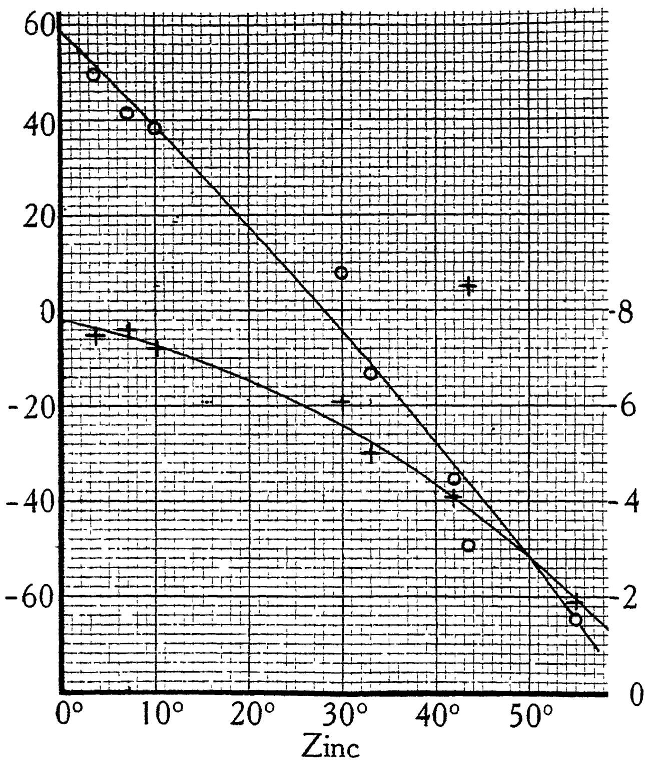

FIGURE 4. Values of E_0 in micro-volts (circles, scale to the left) and Δ in micro-volts (crosses, scale to the right) against the angle between the crystal axis and the length of the rod as abscissa for zinc.

summarize the experimental results. There does not seem to be much question possible as to the best way to draw these curves; only one experimental point is badly off, the value for Δ of the 43.5° specimen. It is of course evident that the percentage error in Δ is much larger than in E_0.

Finally from the smooth curves for E_0 and Δ, the values of a' and b were calculated, and are plotted in Figure 5 against specific resistance.

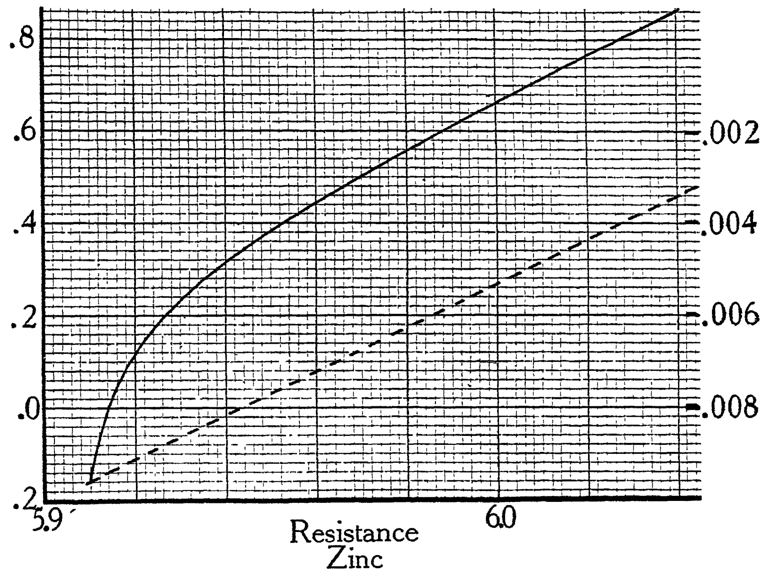

FIGURE 5. Values of a' (full line, scale to left) and of b (dotted line, scale to right) against specific resistance of zinc, a' is closely related to the Peltier heat, and b to the Thomson heat; see equation on page 114.

In computing the specific resistances from the angles of the axis the values $\rho_{11} = 6.13 \times 10^{-6}$ and $\rho_{\perp} = 5.93 \times 10^{-6}$ were used. It appears from Figure 5 that the relation between b and resistance is linear within experimental error, but that the relation between a' and specific resistance cannot well be linear.

Bismuth. 10 rods were used, of the material already described under thermal conductivity, of orientations between the cleavage plane and length varying from 0° to 21.5°. The departure of e.m.f. from linearity with temperature is relatively much less for Bi than for

Zn, so that the value deduced from the curves for Δ is relatively much more uncertain. The following values were found (Table I.). In

TABLE I.

THERMAL E.M.F. DATA FOR BISMUTH.

Angle between Cleavage Plane and Length	Total E.M.F. against Cu 20° to 100°	Departure from Linearity at 60°	Average by Groups Angle	Total E.M.F.	Departure
0°	4460×10^{-6}	50×10^{-6}	0°	4500	25
0°	4540	0			
4.5°	4610	0	5.5°	4610	20
6.5°	4610	40			
10°	5040	80	10°	5040	80
17.5°	5080	100	17.7°	5110	50
18.0°	5150	0			
20.3°	5200	0	21.1°	5170	70
21.5°	4900	100			
21.5°	5420	100			

plotting, rods of nearly the same orientation were grouped together. The results by groups are plotted in Figure 6, with the smooth curves.

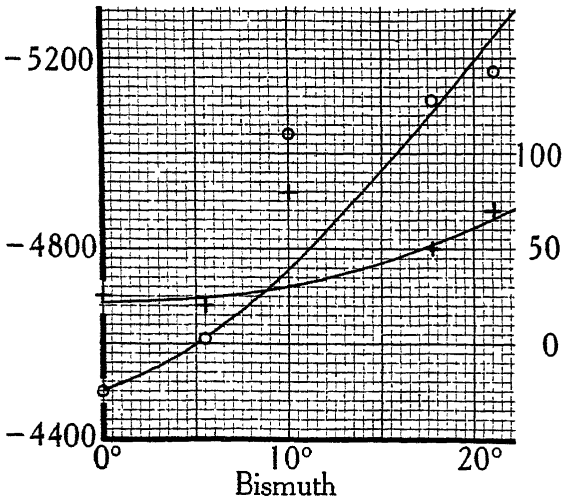

FIGURE 6. Values of E_0 in micro-volts (circles, scale to the left) and Δ in micro-volts (crosses, scale to the right) against the angle between the basal plane and the length of the rod as abscissa for bismuth.

The proper location of the curve for Δ is evidently in much greater doubt than that for E_0.

In Figure 7 are plotted a' and b calculated from these curves at intervals of 0°, 5°, 10°, 16°, and 22°. In converting orientation to specific resistance the values $\rho_{\perp} = 109 \times 10^{-6}$ and $\rho_{11} = 138 \times 10^{-6}$ were used. Again it is evident that within experimental error b is linear against specific resistance, and a' is probably not linear, although the departure is much less than for *Zn*.

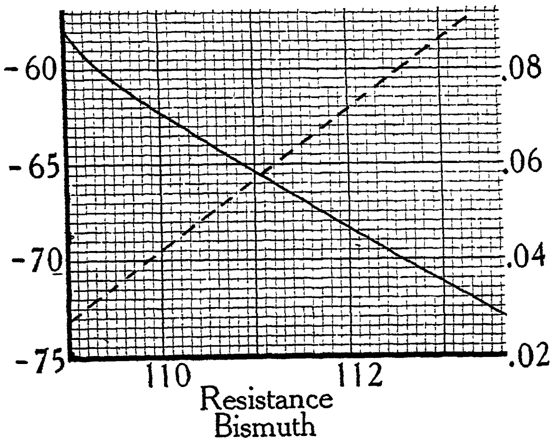

FIGURE 7. Values of a' (full line, scale to left) and of b (dotted line, scale to right) against specific resistance of bismuth. a' is closely related to the Peltier heat, and b to the Thomson heat; see equation on page 114.

Cadmium. 14 rods were used, of which 9 were later selected for the thermal conductivity measurements. These were all of Kahlbaum's best grade of Cd. The specific resistances of these rods were distributed with fair uniformity over the range of values from 6.88 to 8.36×10^{-6}. The values previously found for the specific resistances are: $\rho_{\perp} = 6.80$, $\rho_{11} = 8.30$, so that practically the entire range of possible orientations was represented here. (The high value 8.36 given above against 8.30, the maximum previously found, deviates no more than single samples sometimes do.)

In calculating the results, there was at first considerable question whether the relation between temperature and e.m.f. was really of the second degree or not. Several of the individual curves differed appreciably from the quadratic form, but the discrepancies were

irregular, sometimes the greater curvature being found at the higher temperature end of the curve, and sometimes at the low temperature end. In order to see whether there was any systematic deviation from the second degree relation, the deviations from linearity of all the curves were found at 40°, 60°, and 80°, and the deviations at each temperature plotted against specific resistance. It was found that the irregularities were unsystematically distributed, so that the best smooth curve through the 40° points was identical within experimental error with that through the 80° points and the ordinates of this curve were ¾ of those of the smooth curve through the 60° points. But this is exactly the condition that the curve be of the second degree. All three of these deviation curves were linear in specific resistance.

In Figure 8 is shown E_0 and Δ as a function of specific resistance

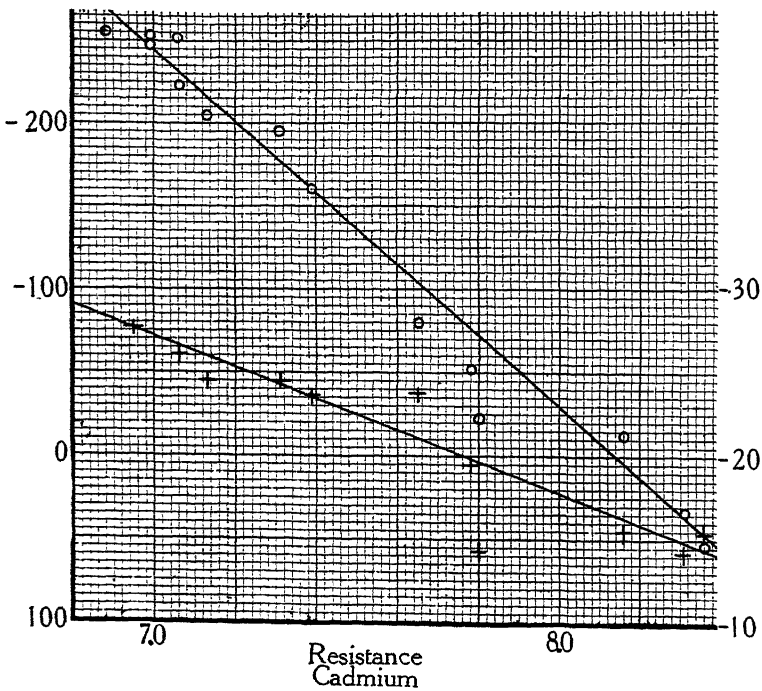

FIGURE 8. Values of E_0 in micro-volts (circles, scale to the left) and Δ in micro-volts (crosses, scale to the right) against the specific resistance in the direction in question as abscissa for cadmium.

(In the curve for Δ several of the values at low specific resistances are averaged into a single point, the values being so nearly coincident that it was not easy to separate them graphically.) In Figure 9 are plotted the values calculated from E_0 and Δ of a' and b. Since E_0

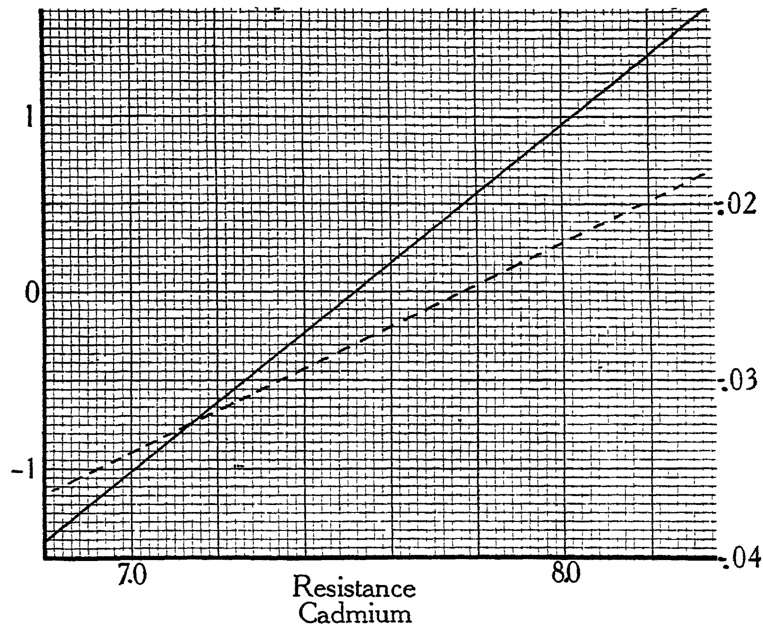

FIGURE 9. Values of a' (full line, scale to left) and of b (dotted line, scale to right) against specific resistance of cadmium. a' is closely related to the Peltier heat, and b to the Thomson heat; see equation on page 114.

and Δ are linear in specific resistance, a' and b must be linear also, so that it was necessary to calculate only two points on each of the curves. Notice that this is the first case yet found of an a' linear with specific resistance.

Tin. 14 rods were used; of these 14 rods, 8 were of Bureau of Standards melting point tin, and 6 were of Kahlbaum's purest grade. No difference whatever could be seen in the behavior of tin from these two sources, and the results obtained with both were averaged indiscriminately. The range of specific resistances of these rods was from 9.89 to 13.23 × 10^{-6} against 9.9 to 14.3 found previously for

the entire range of orientations. However, the distribution of the rods over the range of orientations was not uniform, tin showing a particular disinclination to crystallize with the basal plane perpendicular to the length. Of the samples used 1 had a specific resistance of 13.23, 3 were between 11.1 and 11.2, 1 was 10.6, and the rest were between 9.9 and 10.3.

The relation between thermal e.m.f. and temperature was much more nearly linear than usual, so that the value of Δ is more in error. In Figure 10 are shown the experimental values of E_0 and Δ against

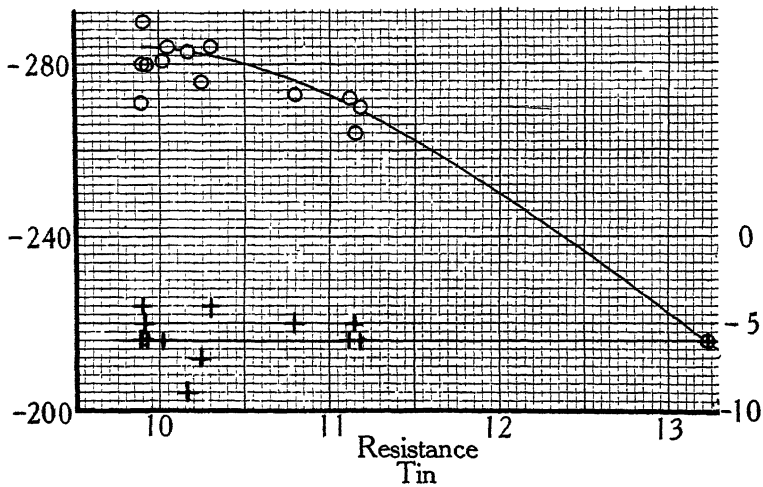

FIGURE 10. Values of E_0 in micro-volts (circles, scale to left) and Δ in micro-volts (crosses, scale to right) against specific resistance in the direction in question for tin.

specific resistance and in Figure 11 the values calculated therefrom for a' and b. Since Δ is constant against specific resistance, it is obvious that b is constant also. Taking as the best value for Δ -6×10^{-6}, the corresponding value of b is -0.0075×10^{-6}.

As in all the other cases, b is linear against specific resistance, but as was also the case with Zn and Bi, a' is not linear within experimental error.

Antimony. Measurements were made on only one specimen of antimony, so that the data are not at hand for a determination of the variation of thermo-electric quality with direction, but since this

measurement was on a single crystal rod, and most previous measurements have been on haphazard aggregates, it seems of interest to record the results.

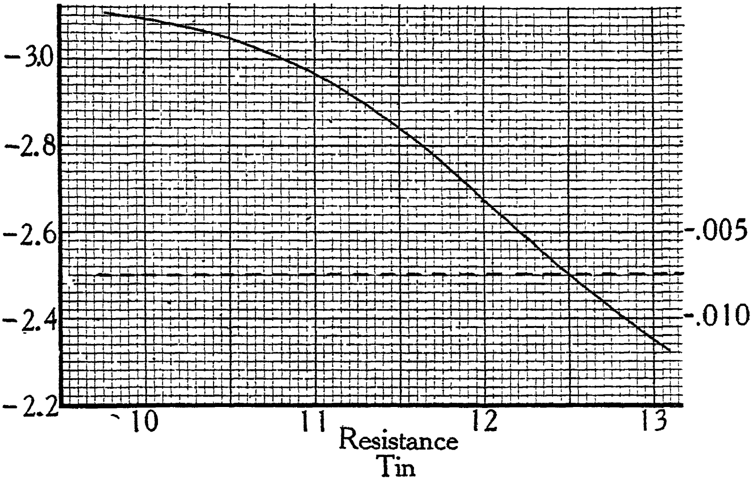

FIGURE 11. Values of a' (full line, scale to left) and of b (dotted line, scale to right) against specific resistance of tin. a' is closely related to the Peltier heat, and b to the Thomson heat; see equation on page 114.

The specimen was of Kahlbaum's purest grade, with the cleavage plane parallel to the length. This was the only one of the specimens investigated for which there was hysteresis between readings with increasing and decreasing temperature of more than the experimental error. The e.m.f.'s with decreasing temperature were about 2.5% lower than those with increasing temperature, the difference therefore being in a direction the reverse of ordinary hysteresis. The mean of the increasing and decreasing readings was used in calculating the results which were as follows:

$$E_0 = +3850 \times 10^{-6} \text{ volts}, \qquad \Delta = +135 \times 10^{-6},$$

whence

$$P_{\mathrm{Cu-Sb}} = \tau[58.25 + .169t] \times 10^{-6}.$$

This is more than twice as high as the value found by Matthiesen[7] for crystalline Sb.

Tellurium. Results, not very satisfactory, were obtained for 3 specimens. The difficulty of making castings which are truly one

grain is even greater than for Bi, and I have not yet attained success. The requirements here are much more exacting than in the previous work because the specimens must be much longer. The specimens investigated here were doubtless not all one grain, but the grains of which they were composed all had very nearly the orientation given. The tellurium used was from the Raritan Copper Works, to whom I am much indebted for specially refining it to remove all selenium. The properties of this Te are reported in greater detail in a previous paper.

The measured e.m.f.'s against temperature are shown in Figure 12. There is no consistent variation of e.m.f. with direction. The curvature is large, corresponding to a Thomson heat much larger than for any of the other metals.

The specific resistance of 2 of the 3 samples was measured; that of the 7° sample was 0.0597 ohms per cm. cube, and that of the 12.5° sample 0.0613.

Theoretical Discussion.

Consider a thermo-couple composed of a straight crystal rod running from a hot region in which the temperature is uniform to a cold region in which the temperature is also uniform. The circuit is to be completed by a copper wire (Figure 13). Then it is a matter of experiment that the e.m.f. of the couple depends only on the terminal temperatures and the orientation of the rod with respect to the crystal, and not at all on how the copper wire is attached at the ends, or on any other modification which may be made in the two regions at constant temperature. In particular, the e.m.f. is the same whether the copper wire is attached as at A to a surface perpendicular to the length of the rod, or whether it is attached as at B to an oblique surface. Within the hot region, heat is absorbed in the one case at the surface A, and in the other case at the surface B, and since the total e.m.f. is the same and no modification has been made in any other part of the circuit, the heat absorbed at the two surfaces A and B must be the same. But if the orientation of the rod with respect to the crystal were changed, the heat absorbed locally at the surface of attachment of the copper wire would in general change, because the total e.m.f. changes with the orientation. Hence it follows that the heat absorbed when a current passes out of a crystal rod into an isotropic medium depends on the direction of flow of the current in the rod, and not on the orientation of the surface by which it leaves (of course it also depends on the nature of the isotropic medium).

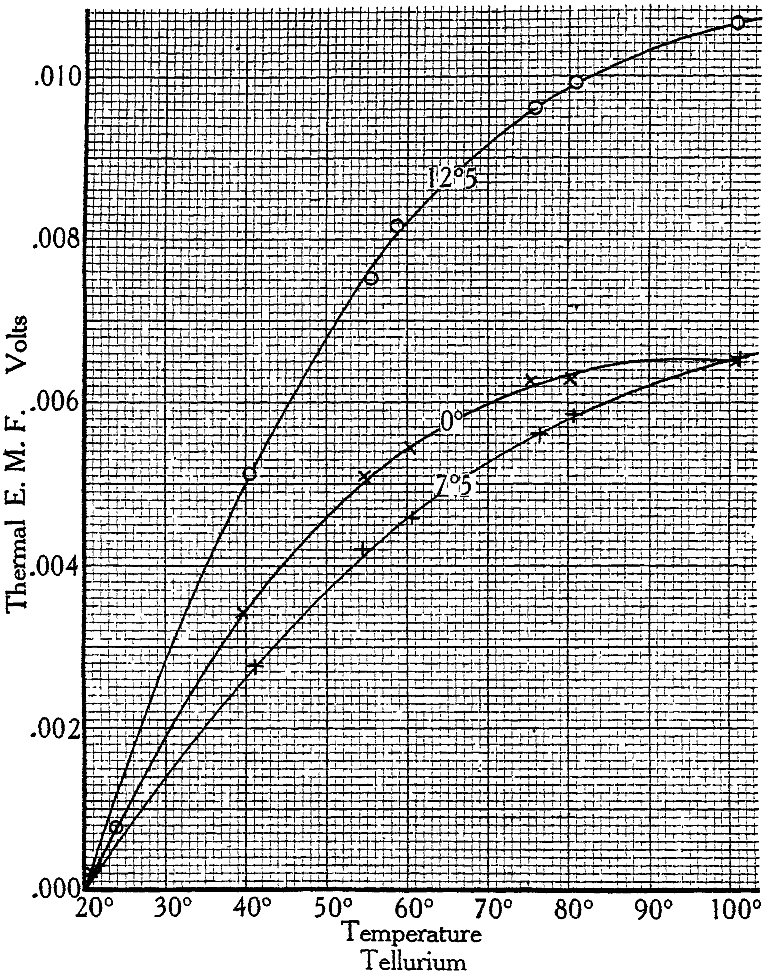

FIGURE 12. Thermal E.M.F. against copper in volts as ordinates plotted against the temperature of the hot junction as abscissa for rods of tellurium of the indicated angles between the crystal axis and the length of the rod.

Let us now suppose that the copper terminal is attached at the end of a right angled arm as shown in Figure 14, the crystalline orientation being uniform throughout the entire specimen. The total e.m.f. is the same as in the first case, because no modification made in

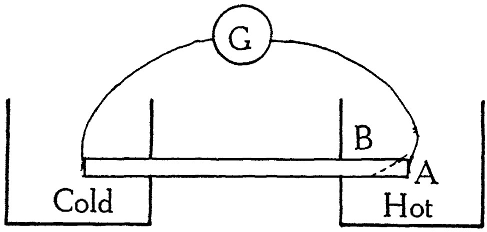

FIGURE 13. Schematical representation of the connections in measuring the thermal E.M.F. of a crystal rod against copper. The E.M.F. is the same whether the crystal rod is cut off perpendicularly as at A or obliquely as at B.

the region at constant temperature affects the e.m.f., and therefore the total heat absorbed in the hot region is unaltered. But the heat absorbed on leaving the surface C is now that appropriate to a flow in the crystal at right angles to the original direction. This is in general different from the original heat. There must therefore be an absorption of heat somewhere else in the hot region, and the principle of sufficient reason suggests that this can be only where the direction of the current flow changes. The amount of heat so absorbed where the direction changes is determined by the requirement that together with the surface heat at C it add to the right amount.

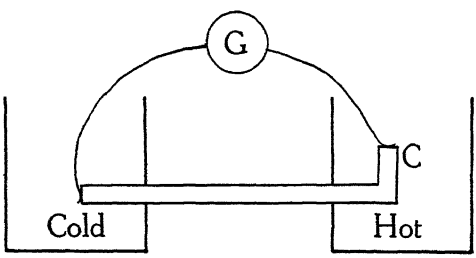

FIGURE 14. The thermal E.M.F. is the same in this figure as in figure 13.

We are thus led to the concept of an internal Peltier heat in a crystal which occurs when the direction of current flow changes at constant temperature. The magnitude of this effect is obviously determined when the ordinary Peltier heat at emergence is known as a function of direction, for it is determined by the simple requirement that the internal Peltier heat on changing from one direction of flow to another is equal to the difference of the emergent Peltier heats for these two directions of flow.

The necessity for the existence of this internal Peltier heat does not seem to have been previously noticed; it is not mentioned by either Voigt or Thomson.[8] The inclusion of it will essentially modify Voigt's analysis. It would seem that the mere existence of this effect should have important consequences on our theoretical views as to the nature of electrical conduction; it is hard to see according to any of the usual pictures why there should be any such effect at all.

For theoretical considerations the dimensions of P are important. P is heat absorbed per coulomb, or it may also be expressed as heat absorbed per electron. This means that the effect cannot be a momentum or a kinetic energy effect arising from a difference of natural velocity of the electrons in different directions in the crystal, for such effects would be proportional to the velocity of each electron, so that the resultant effect per electron would be proportional to the current, and therefore not a constant. In explanation, it almost seems necessary to ascribe to the electron a polar character, and to suppose that in the crystal there are different orienting forces depending on the direction of motion in the crystal. One is reminded of the magnetic doublet character which Compton[9] would ascribe to the electron.

The total e.m.f. in such a circuit as we have been considering is maintained by the Peltier heats at the two ends, and by the Thomson heat in the region where there is a temperature gradient. The relations between the Peltier heats and the Thomson heats for a long slender rod of any orientation with respect to the crystal we assume to be given by the thermodynamic analysis of Thomson, so that for any definite direction we have the relations:

$$P_{\mathrm{Cu-Crys}} = \tau \frac{dE}{d\tau},$$

$$\sigma_{\mathrm{Crys}} - \sigma_{\mathrm{Cu}} = \tau \frac{d^2E}{d\tau^2},$$

where E is the total e.m.f. for the direction considered, and σ is the Thomson heat for current flow in the crystal in that particular direction. Now it seems highly probable that the analysis of Voigt for the heat absorbed internally when the current flow is straight may be accepted without change. Voigt puts the Thomson heat absorbed reversibly equal to the work received by the current in flowing through a Thomson "e.m.f." This Thomson e.m.f. is in nature a vector, and as suggested by the adequacy of the ordinary

thermodynamic analysis for an isotropic substance, we assume it is a linear vector function of the temperature gradient. The coefficients of the linear vector function are the Thomson coefficients of the crystal. Precisely the same symmetry considerations apply to them as to the coefficients of other linear vector functions, for instance, to the electrical resistance in different directions, or to the thermal resistance; the symmetry relations are the same and the manner of variation with direction is the same. In particular, the Thomson coefficients for the crystals considered here belonging to the trigonal, tetragonal, and hexagonal systems have rotational symmetry about the principal axis and the variation with direction is given by the equation

$$\sigma_\theta = \sigma_{11} \cos^2 \theta + \sigma_\perp \sin^2 \theta,$$

where θ is the angle between the direction considered and the principal axis, and σ_{11} and $\sigma_\perp$ are the Thomson coefficients for flow along and at right angles to the axis.

It is a consequence that σ is a linear function of the specific resistance, just as was the reciprocal thermal conductivity.

The Peltier heat at the surface, as well as the internal Peltier heat, was not at all considered by Voigt, so that his formulas cannot be applied without further examination to any actual thermo-couple. (The inadequacy of the analysis of Voigt may be inferred from his formula 433 on page 550, according to which the total heat absorbed in a complete thermo-electric circuit must be zero, so that there is no provision made for the source of the integral e.m.f. around the circuit.) The question that we now have to consider in supplementing Voigt's analysis is what are the necessary symmetry relations on P? The symmetry relations on σ involved essentially the assumption that it was a linear vector function of the temperature gradient. Now P is a function of direction, but there seems to be no natural argument for the symmetry relations of a *general* direction function such as there is for a *vector* function. In particular there would seem to be no reason for expecting P to be a linear function of the direction cosines—why might it not as well be a linear function of the direction tangents? As far as I can see, there is no reason to expect any special manner of variation of P with direction, and in particular no reason at all to expect that P should be the same function of direction as σ. It would follow that the total e.m.f. of a circuit would not necessarily be expected to follow Voigt's formula, and in particular there is no reason to think that the total e.m.f. ought to be a linear function of the resistance.

It does, however, seem natural to expect that P should have rotational symmetry about the principal axis, although I can see no mathematical necessity for such. This is strongly suggested by the experiments. When I made the experiments, I had not examined Voigt's analysis carefully, and expected his results to apply. Therefore in determining the orientation of the crystal rods I determined only the angle between the length of the rod and the principal axis. If P has rotational symmetry, this is adequate. That it is adequate is suggested by the experimental results, since with only a few exceptions, smooth curves are obtained on plotting total e.m.f. against orientation with respect to the axis. If two parameters were required, the curves in one parameter would not be expected to be smooth. In the case of Bi, I have since determined that, in the two specimens whose cleavage planes were parallel to the length, the secondary cleavage planes in one rod made an angle of 66° with the length, and in the other an angle of 81°, with corresponding values for E_0 of 4460 and 4540×10^{-6} volts, which probable differ no more than the experimental error. One may at least draw the conclusion that for these four metals P does not depend importantly on orientation with respect to the secondary crystal axes.

That P does not have the symmetry relations of Voigt has already been brought out in the detailed presentation of data. In all cases the Thomson heat is within experimental error a linear function of electrical resistance, but for Bi, Zn, and Sn, P is not such a function.

An examination of the signs shows that there is no universal relation between heat absorption and the change of direction of flow. Thus for Sn and Bi heat is absorbed when the direction of current flow changes from parallel to perpendicular to the axis, whereas for Zn and Cd heat is given out for the same change of direction.

The fact that thermal e.m.f. varies with direction in a crystal has an interesting bearing on a question which has been much discussed, namely the law of Magnus. This law states that in a circuit composed of a single perfectly homogeneous metal no circuital e.m.f.'s can be generated by any distribution of temperature. It has been claimed a number of times that the law is not true, but the concensus of opinion seems to be that such apparent exceptions are to be explained by lack of perfect homogeneity in the metal. Now it is at once obvious that this law can have no application to a crystal, for high e.m.f.'s may be generated in such circuits as that shown in Figure 15 cut from a single crystal. Now of course all metals of practise are multi-crystalline, the grains being presumably oriented at haphazard.

Experiments made on a large scale would be expected to verify the law of Magnus, but when any part of the circuit becomes so small that the individual crystals are comparable in size with the cross section of the circuit, one might expect these characteristically crystalline properties to produce an appreciable net effect, and the law of Magnus to fail. It is not quite evident from the experimental evidence now in hand whether to expect such small scale effects with metals crystallizing in the cubic system. If the Peltier heat satisfies the same symmetry relations in a cubic crystal as does the Thomson Heat, then we should not expect such an effect, but we have seen that there seems to be no simple necessary connection between P and direction, so that we need not expect P necessarily to have spherical symmetry

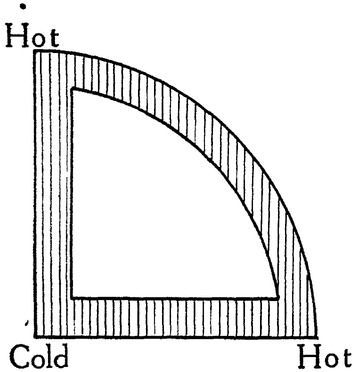

FIGURE 15. To illustrate conditions under which current may flow in an unequally heated circuit cut from a single crystal. If the materials were amorphous, no current would flow.

in a cubic crystal. If P has not spherical symmetry, it need not average to zero when the cross section of the circuit is composed of comparatively few grains. Entirely apart, however, from these crystalline effects, there is the consideration that non-uniform temperature gradients cannot be maintained in a solid without producing mechanical stresses, and so making the material non-homogeneous.

It seems then that interest in the law of Magnus is reduced to a somewhat academic position. It is a result of experiment that any such effects are small, but under properly chosen conditions of experiment we may expect such effects to be found. Two interesting questions remain, however: does the law of Magnus hold for a liquid metal such as mercury? And in a single crystal rod, in which there is a

uniform temperature gradient and no mechanical stress, is the Thomson heat absorbed by the current a function only of the temperature difference between two points and not a function of the temperature gradient?

Average Values. There are no previous results on single crystals to compare with these (except for Bi), but it is natural to expect that previous results on polycrystalline metals should agree with some sort of an average, throughout the crystal, of the results found here. The theoretical discussion indicates what sort of agreement to expect. The Thomson heat satisfies the symmetry relations of Voigt, so that his value for the average should apply. The Peltier heat seems to have no such symmetry relations, so that Voigt's expression for the average does not apply, but we expect, nevertheless, an agreement as to sign and order of magnitude between the observed P, for polycrystalline metals, and the average calculated for the crystal by Voigt's formula.

In Table II. are collected the values for P and σ at 0° C. against copper taken from my previous paper on extruded wires,[6] and the values for P and σ in different directions of the crystals of this paper. In the case of Bi, which has a very large P, there is agreement in both sign and order of magnitude. σ is also of the right sign, but when averaged by Voigt's formula over all directions in the crystal it is evident that σ for the crystal will be much larger than for the extruded wire. But it must be remembered that there is considerable error possible in the σ given for the crystal, and it is also possible that in the extruded wire all orientations were not uniformly represented, so that one cannot be perfectly sure that the data for Bi are inconsistent with some sort of average law. But the other metals seem to make this impossible. Both P and σ for all directions in Sn have the wrong sign to agree with previous values for Sn wire. Cd crystals have the wrong sign for σ and a value for P also of the wrong sign and at least 10 fold too small numerically. With Zn it is not impossible that some sort of an average of the P of the crystal should agree with the P of the wire; σ furthermore has the right sign, but the average for the crystal is about 4 times too small. One may try to improve the agreement, on remembering that the copper of these experiments may have been different from that used previously, by correcting the values given for the extruded wire by a constant additive correction applied to all the P's, and another additive correction to all the σ's. But a little trial will show that this is not possible; a change that improves the agreement in one place makes it worse in another.

TABLE II.

Comparison of the Thermal E.M.F. against Cu of Isotropic and Unicrystalline Metals.

Metal	Isotropic		Unicrystalline		
	Peltier Heat at 0° C Against Cu.	Thomson Heat at 0° C Against Cu.	Specific Resis.	Peltier Heat at 0° C Against Cu.	Thomson Heat at 0° C Against Cu.
Sn	$-2.517 \times 10^{-6} \tau$	$-.0110 \times 10^{-6} \tau$	9.9×10^{-6} 13.0	$3.10 \times 10^{-6} \tau$ 2.35	$.0075 \times 10^{-6} \tau$ .0075
Cd	9.225	.227	6.8 8.3	—1.41 +1.54	—.036 —.019
Zn	.270	—.0196	5.910 6.039	— .147 + .854	—.0097 —.0035
Bi	—77.20	.0223	109 113	—57.8 —71.5	.0275 .0875

The conclusion seems to be forced that the thermo-electric properties of a polycrystalline aggregate (at least of non-cubic metals) cannot be computed from the average of the properties of a single crystal in the same way that the electrical resistance or the thermal conductivity can be calculated. In explanation it is to be noticed that, in any polycrystalline aggregate of non-cubic metals formed in the usual way by casting, there must be intense internal stresses, because of the unequal thermal expansion of the grains in different directions, and that thermo-electric properties are much more sensitive to such stresses than resistance or thermal conductivity. If this is correct, one will in the future attach less theoretical significance than hitherto to thermo-electric properties measured on polycrystalline aggregates of these metals.

Summary.

1. Thermal Conductivity. The thermal conductivity of Bi, Zn, Cd, and Sn is measured at room temperature for different directions in the crystal. It is found that Voigt's symmetry relations are satisfied in that in any single crystal the reciprocal of thermal conductivity varies linearly with electrical resistance as the orientation changes. The generalized Wiedemann-Franz law, however, does not hold for all directions in a crystal in that the ratio of thermal to electrical conductivity is in general a function of the orientation. Within experimental error it is not impossible that the Wiedemann-Franz ratio is constant for Bi and Sn, but in Zn the thermal conductivity varies more rapidly with direction than does the electrical conductivity, and Cd the variation of thermal conductivity is less rapid.

2. Thermal E.M.F. The thermal e.m.f. against copper is measured between 20° and 100° C. as a function of direction in the crystal for Bi, Zn, Cd, and Sn, and isolated results are also found for Sb and Te. In general the thermo-electric force varies greatly with direction. From the thermal e.m.f. data the Peltier and the Thomson heats are calculated. Voigt's symmetry relations are shown to be satisfied by the Thomson heat, which is a linear function of electrical resistance. The Peltier heat, on the other hand, was apparently not considered in Voigt's analysis, and these experiments show that the symmetry relations to which it is subject are not the same as those for the Thomson heat. It is probable that the Peltier heat has rotational symmetry about the principal crystal axis, but there appears to be no necessary restriction as to its variation in directions inclined to the axis. It is pointed out that the Peltier heat depends only on the

direction of current flow within the crystal just before emergence, and not on the orientation of the surface through which it emerges. It is a consequence that there is an internal Peltier heat, i. e., a reversible absorption or generation of heat where the direction of current flow changes within the crystal. The mere existence of this effect should be most important for theories of electrical conduction. It is also a consequence of the difference of thermal properties of a crystal in different directions that the generalized law of Magnus cannot hold for a crystal, but in general thermal currents will flow in an unequally heated closed circuit cut from a single crystal. Finally, the thermo-elective properties of an ordinary polycrystalline aggregate of non-cubic crystals cannot be found by averaging the properties of the single crystals in different directions.

It is a pleasure to acknowledge the assistance received from Mr. E. T. Lane in making nearly all the readings of thermal e.m.f. It is also a pleasure to acknowledge financial assistance received from the Rumford Fund of the American Academy.

The Jefferson Physical Laboratory,
Harvard University, Cambridge, Mass.

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Proceedings of the American Academy of Arts and Sciences.

VOL. 61. NO. 5.—APRIL, 1926.

MEASUREMENT OF THE COMPRESSIBILITY OF THE ALKALI HALIDES.

BY J. C. SLATER.

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Received January, 1926. Presented February 10, 1926.

Experimental work on the compressibility of eleven alkali halides, and its variation with pressure and temperature, has already been reported briefly by the author[1] in a paper dealing chiefly with theoretical deductions from the data. In the present paper, experimental details of the same investigation will be given. The measurements were carried out in Professor Bridgman's laboratory, using his recently developed method of measuring compressibility, and my sincerest thanks are due to him for his advice and interest. The samples were artificially prepared single crystals of the salts. The first section of the present paper deals with the preparation of the crystals; the second with the method of measurement; and the third with the results.

I. Preparation of Single Crystals.

For measuring compressibility, it is necessary to have sound samples, without cracks or flaws. The only satisfactory way to secure this result, with salts such as the alkali halides, seems to be to produce single crystals. Any aggregation of crystals, as in a metal, would lead to suspicion that there were flaws, which on account of the opacity of inhomogeneous material could not be detected. The first part of the research was therefore directed toward producing single crystals, large enough to make a sample out of one crystal. Methods of crystallizing from water solution were first tried, but without much success. Some of the salts are hygroscopic and cannot be crystallized from solution anyway, and in all of them there would be danger of mechanical inclusion of water. These facts, together with the poor success of my attempts to crystallize from solution, led me to the conviction that the most hopeful method lay in crystallizing from the molten salt at high temperature. Preliminary experiments showed that transparent crystals of considerable size could form very rapidly on solidification of the melt, although the normal state was a snow-like aggregate useless for the measurements. The following procedure

[1] Slater, Phys. Rev., 23, p. 488, 1924.

was finally worked out for making the crystals as large as possible, and extracting them without damage. Undoubtedly a more satisfactory process could be developed without great trouble; but the method used had the advantage of great simplicity of apparatus, and rapidity, and proved sufficient for supplying the necessary samples.

The salt was melted in a platinum crucible about an inch and a half in diameter, placed on an alundum stand about in the center of a vertical tubular electric furnace just large enough in diameter to accommodate it. The range of melting points for the salts used was roughly from 450° C. to 900° C. No material but platinum was found capable of resisting all the fused salts. The furnace had a rheostat for adjustment. It was open at the top, so that it was possible to look in, and see when the salt fused. After fusion, the furnace was adjusted so as to keep the salt somewhat above its melting point. The appearance of the salt gave a sufficient indication of the temperature, without any measuring device.

After fusing the salt and letting the liquid come to approximately constant temperature, a procedure was followed whose object was to cool a small area in the center of the top surface of the liquid, so that crystallization should start from there and spread through the crucible. By this means the crystallized material was in the form of a small number of crystals, rather than a large number as would be the case if there were many centers of crystallization. The method was to blow a sharp jet of air on the surface of the liquid, directed against a small platinum wire dipping below the surface. The air came from a compressed air tank, through a reducing valve, and was led into the furnace from the top through a small quartz tube, about an eighth of an inch outside diameter, passing down the axis of the furnace. The tube reached to within about a quarter of an inch from the surface. The platinum wire was held in place simply by sticking up inside the tube, being slightly bent so as to stay in place by friction, and was bent at its lower end into a small loop, which projected below the surface. The purpose of the wire was two fold: to furnish a point for the crystallization to start, and to provide a handle for lifting out the solid after it had formed. It would presumably have been better to suspend a seed crystal in the loop. This was tried a few times, with fair results, although it was difficult to prevent the seed from melting before the surrounding liquid was cool enough to start crystallizing; but in general it was not used, because only one melt was made of each salt, and there were no seeds to use. After blowing for a few minutes, crystallization would commence, in the form of a glass like

lump attached to the wire. This gradually would spread until the glassy material covered the surface. At the same time of course the crystalline material penetrated down. It hardly ever reached the bottom of the crucible, however; a stage would be reached when an aggregate of crystals would commence to form below the glassy material. This could be observed through the glassy salt, as a whitish appearance rather suddenly forming. The whole process occupied on the average perhaps half an hour. The careful adjustment of the air jet and of the temperature of the furnace, so as to crystallize fast enough to prevent re-melting of what had already crystallized, but not fast enough to start other flaky crystals on the surface, demanded considerable care.

When the crystalline material had formed, it was necessary to remove it from the crucible before allowing it to cool; otherwise it invariably cracked. This was easily accomplished by removing the quartz tube, lifting the salt and crucible bodily from the furnace by the platinum wire, and playing a flame on the outside of the crucible until the surface of the salt was melted and the crucible fell off. The crystalline material was then immediately replaced in the furnace, the current turned off, and the salt allowed to cool down with the furnace. By this method cracking was entirely avoided.

After cooling, the glassy mass was examined. It was found in general that the salts with large atomic weights, such as KI and RbI, had the largest mass of transparent crystals, while those of low atomic weights, as LiF and NaF, had the smallest; thus one melt of RbI was entirely converted into a single crystal, while on the other hand there was no crystal half an inch long from the melt of LiF. Generally there were four or five single crystals, grown together, making up the crystalline mass. These were separated by starting cuts with a jeweler's saw along the surface of separation, after which they broke apart. The directions of the planes of cleavage in an individual crystal were then found by chipping small pieces from the corners. Pieces were cut out, of approximately the size desired, surrounded by cleavage planes. By having all the faces cleavage planes, and by seeing that the material was perfectly clear, it was possible to be sure that a single crystal was being used.

The samples used for measurement were cylinders, three-sixteenths of an inch in diameter and about half an inch long. Blanks of square cross section were first made, as described above, one of the crystal axes being along the long dimension of the blank. These were then trimmed to approximately cylindrical form with a knife. The final

shaping was done in a bench lathe. It was found possible to turn the crystals without serious danger of breakage if they were held in the chuck surrounded with a cushion of paper saturated with oil, and if the tool was very sharp, used at high speed, and with a small cut. Finally the ends were stoned down on an oil stone, until they were of a mirror-like smoothness. Some of the salts were hygroscopic, and to prevent tarnishing by moisture they were kept moistened with oil while working, and the finished samples were kept under oil.

II. Measuring Apparatus.

The method of measurement was that described by Bridgman.[1] It is a measure of linear compressibility; but for cubic crystals, which are isotropic, the cubic compressibility can be found directly from the linear. A sample—in this case a cylinder of crystal—is placed under hydrostatic pressure. One end is held fixed, and the motion of the other end, as the crystal contracts, is magnified by a lever. The end of the lever carries a resistance wire, which slides over a contact fixed to the apparatus, so that the length of wire between the contact and another contact fixed to the wire varies linearly with the change in dimensions of the sample. The resistance of this piece of wire is then measured on a potentiometer, and, being proportional to the length, is a direct indication of the length of the sample. The only difference of any importance between the apparatus as it was used in this experiment and Bridgman's original apparatus came from the small samples used. The samples were held in a cylindrical steel jacket, its outside dimensions being the same as the size of the sample used by Bridgman, and the center just large enough to make an easy fit for the crystal. The crystal rested at each end against steel cylinders of the same diameter that it was, rather than against bearing points as in the case of the metal samples. One of these cylinders was made new for each sample, and of such length that it and the sample added up to a standard length. This made it possible to use samples of the most convenient length in each case. It was found necessary to polish on an oilstone the surfaces of crystal and steel cylinders which came in contact; for any variation in the length of the column of crystal and steel, resulting, for example, from irregularities in the steel digging into the soft crystal, would be communicated to the measuring apparatus as much as a real change in length of the crystal. At first the surfaces were merely finished in the lathe, and unexplained irregularities

[1] Bridgman, Proc. Am. Acad., 58, p. 165, 1923.

in the results were observed. These were traced to the rough ends, and when the practice of stoning was adopted, the irregularities disappeared.

The lever apparatus and potentiometer were all calibrated together, by removing the lever apparatus from the pressure cylinder, putting a micrometer screw in place of the sample, and observing the change of potentiometer reading as the screw was turned through a known distance. The magnifying power—the ratio of displacement of the potentiometer slider to the displacement of the end of the sample—was found to be 2292, with a probable error of about three-tenths of a percent. Any individual reading of the potentiometer was likely to be in error by about two millimeters of the slide wire, corresponding roughly to one micron in the length of the sample. This amount represented the variability of the apparatus.

The principal corrections arose from the change of specific resistance of the resistance wire with pressure, from the thermal expansion of the resistance wire, and from the contraction of the lever apparatus under pressure. The first affected the result because the change in resistance of the wire depended both on its length and specific resistance. The correction was made by using Bridgman's measurement of the change of resistance of nichrome with pressure. The thermal expansion was allowed for by using the known thermal expansion of nichrome. The third, the contraction of the apparatus under pressure, is simply another way of expressing the fact that the measurement is not one of absolute linear compressibility, but of compressibility relative to steel. These corrections were all small; except for LiF, the least compressible salt, the total correction to the compressibility was not more than two percent. Instead of making corrections on the individual experimental points, the constants of the experimental curves were determined as described in the next paragraph, and then corrections were made on the constants.

Measurements were made on each salt every thousand atmospheres up to twelve thousand atmospheres. The total displacement of the slider varied from ten centimeters in the least compressible salt to ninety in the most compressible. An individual reading, varying by about two millimeters, was thus likely to vary from two-tenths of a percent to two percent of the total displacement. The displacement was, as accurately as could be determined, a quadratic function of the pressure. Equations were fitted to these curves, and the two constants of the equations gave the initial compressibility and its initial change with pressure. The equations were found as follows: The

desired equation is of the form $d = ap + bp^2$, where d is the displacement, p the pressure, a and b constants. We can then write it $d/p = a + bp$. Thus if d/p is plotted against the pressure, the result should be a straight line. This method was used, the experimental points being plotted, the results in every case lying on a fairly satisfactory straight line, and the constants were found simply by drawing a straight line through the points and reading off its constants. The errors were magnified in this form of plotting, particularly at low pressures, but mental allowance was made for this in drawing a line. The equations of the second degree curves were also found by least squares, for guidance, although the results of this method were not blindly followed. After finding the constants a and b of the quadratic, the corrections were made on them, and the desired relations found from them. The compressibility was found from a alone, while the change with pressure depended principally on b. The analysis by which this was done, while slightly complicated, was perfectly straightforward, and need not be given.

Measurements were made at two temperatures, 30° C. and 75° C. The compressibility would be expected to vary with the temperature, but not to an observable extent the change of compressibility with pressure. Corresponding to this, the curves connecting d/p with p for the two temperatures should have the same slope but different intercepts. This was found in every case to be true, within the limit of error of the experiment. By combining the data for a given sample at different temperatures, and assuming that the slopes of both curves should be the same, it was possible to find the slope more accurately than from one curve alone. In some cases the constants obtained by least squares for the two temperatures did not agree, but those were found to be the cases where the individual points lay farthest from the curves, and in no case was it necessary to do violence to the data to assign the same slope to each.

The compressibility, determined from the slope of the curve of d against p, or the intercept of d/p against p, could be found in general to a percent or better. The significant errors were the error in determination of the constant for the curve, and the error in the constant of the apparatus, already stated as about three-tenths of a percent. The change in compressibility with pressure had an error perhaps five times as great, arising almost entirely from the inaccuracy in determining the constants from the data. This is found essentially from the difference in actual displacement at 12,000 atmospheres and the displacement which would occur if it varied linearly with the

pressure; and as this was in general about a fifth of the total displacement, and was subject to the same absolute errors, the relative error was greater in proportion. The change of compressibility with temperature was found from the compressibility as determined at two separate temperatures, and differing by perhaps three percent. The error is thus large, only the order of magnitude being given by the results. The errors were not quite as large as might be imagined, however; for the measurements at the two temperatures were made without taking the apparatus apart, and errors were likely to repeat; and only the difference in calibration at the two temperatures was used, determined from known constants, and not the calibration itself. Thus it is likely that the results are correct to twenty, or even ten, percent.

III. Detailed Data.

The measured quantities were defined as follows: If v is the volume of a certain quantity of substance, v_0 its volume under zero pressure, then the compressibility is defined as

$$\kappa = \frac{1}{v_0}\left(\frac{\partial v}{\partial p}\right)_T.$$

If κ_0 is the value of the compressibility under zero pressure, then the change of compressibility with pressure may be conveniently defined as

$$\psi_0 = \frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial p}\right)_T,$$

the derivative being taken at zero pressure. The two constants κ_0 and ψ_0, for a fixed temperature together with the change of compressibility with temperature, $1/\kappa_0(\partial\kappa/\partial T)p$, are the quantities measured. As stated above, it was at first not the practice to stone the ends of the crystal and steel cylinders, and this resulted in irregularities, but so far as was known in no outstanding errors. A considerable number of readings were made in this way, and they are given in the discussion to follow, although they are not weighted as much in determining the averages at the later readings. Measurements were made on eleven salts: LiF, LiCl, LiBr, NaCl, NaBr, KF, KCl, KBr, KI, RbBr, and RbI. Measurements had been previously made by Richards and Jones at low pressures on the chlorides, bromides, and iodides of sodium and potassium[1]; by Madelung and Fuchs[2] on NaCl

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[1] Richards and Jones, J. Am. Chem. Soc., 31, p. 158, 1909.

[2] Madelung and Fuchs, Ann. d. Phys., 65, p. 289, 1921.

and KCl at low pressures; and by Adams, Williamson, and Johnston[1] at high pressures on NaCl. Since the work described in the present paper was performed, measurements have also been made by Richards and Saerens[2] on the lithium and rubidium salts at low pressures. These results are discussed under the individual salts. The detailed results follow:

LiF. This salt was from Eimer and Amend, stated by them to be pure. It is the most difficult salt of all to crystallize, and it was impossible to obtain a single crystal large enough, so that finally two crystals were fitted together. It was so hard and brittle that it could not be turned, but was shaped by hand. The bearing faces, however, were made as flat as with any other samples, and I do not think the sample as finally used was unsatisfactory. On account of the low compressibility, the relative errors were large. I presume the error in the κ_0 may be several percent, and in ψ_0 possibly fifteen percent, although the values of ψ_0 found from the curves at the two temperatures separately agreed within six percent. The absolute errors are probably no larger than for any other salt. The values found are

$$-\kappa_0 = 1.53 \times 10^{-12}/\text{dyne/cm}^2, \quad -\psi_0 = 11.7 \times 10^{-12}/\text{dyne/cm}^2,$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 1.9 \times 10^{-4}/\text{degree}.$$

Herafter all compressibilities and changes of compressibility with pressure will be expressed in reciprocal dynes per square centimeter, and this unit is to be understood when it is not stated explicitly. Similarly changes of compressibility with temperature are in reciprocal degrees centigrade.

LiCl. This was from stock. It was crystallized without serious difficulty, although two trials were necessary, and a fairly good sample was obtained, perfect except for a small slightly cloudy place in one corner. It was kept covered with oil, and showed only a slight tarnish on the surface; its hygroscopic character did not appear to interfere with the reliability of the results. Measurements were made with the apparatus before its improvements; they were entirely satisfactory, and gave

$$-\kappa_0 = 3.41 \times 10^{-12}, \quad -\psi_0 = 19.8 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.9 \times 10^{-4}.$$

[1] Adams, Williamson, and Johnston, J. Am. Chem. Soc., 41, p. 12, 1919.

[2] Richards and Saerens, J. Am. Chem. Soc., 46, p. 934, 1924.

Richards and Saerens' results for the compressibility was 3.7×10^{-12}. Unfortunately, between the time of measurement and the time when the apparatus was improved, a drop of water found its way to the crystal, and it disintegrated. Since there was no more crystallized material, and since the readings had appeared to be perfectly good, measurements were not repeated after the improvement.

LiBr. Not much difficulty was found in crystallizing this salt, which was also from Eimer and Amend. Measurements were made only after the improvement of the apparatus; the runs were good, with small variations, and the runs at the two temperatures gave values of ψ_0 differing by about four percent. The final values are

$$-\kappa_0 = 4.31 \times 10^{-12}, \quad -\psi_0 = 24.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 8.4 \times 10^{-4}.$$

Richards and Saerens find 5.0×10^{-12}.

NaCl. Natural rock salt crystals were used. Runs with the apparatus before improvement, were made on two samples; the first, the earliest run made with the apparatus, gave

$$-\kappa_0 = 4.38 \times 10^{-12}, \quad -\psi_0 = 22.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 9.6 \times 10^{-4}.$$

A second gave

$$-\kappa_0 = 4.22 \times 10^{-12}, \quad -\psi_0 = 20.4 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 2.6 \times 10^{-4}.$$

The difference between the compressibilities is no more than was often found before the practice of stoning the faces was adopted. The variation in change of compressibility with temperature is the largest that was found for any substance. The mean of these is

$$-\kappa_0 = 4.30 \times 10^{-12}, \quad -\psi_0 = 21.4 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.1 \times 10^{-4}.$$

After the improvement of the apparatus, a run was made on the first of the two samples above; it gave

$$-\kappa_0 = 4.20 \times 10^{-12}, \quad -\psi_0 = 21.9 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 7.5 \times 10^{-4},$$

in satisfactory agreement with the mean of the previous values, considering their large error. As final, I take the values of κ_0 and ψ_0 from this sample, and for $1/\kappa_0(\partial\kappa/\partial T)_p$ the value 6.8×10^{-4}, giving some weight to the previous runs.

Several people have measured this salt before. Their results are for 20°; reducing this value to that temperature gives $-\kappa_0 = 4.17 \times 10^{-12}$. Richards, making a correction for an old value of the compressibility of steel which he used, found 4.30×10^{-12}; Adams, Williamson, and Johnston's value was 4.12×10^{-12}; and Madelung and Fuchs's, 4.14×10^{-12}. Adams, Williamson, and Johnston also determined ψ_0; their value, corrected for Bridgman's redetermination for steel, was 15×10^{-12}. It is thus seen that the value of compressibility found agrees well with the mean of previous observations, and the change of compressibility with pressure agrees as well with the one previous value as could be expected from the larger error in the method then used.

NaBr. This salt was from stock. Quite a little trouble was found in making the crystal, but the sample was perfectly satisfactory. A run was made before improving the apparatus, giving

$$-\kappa_0 = 5.08 \times 10^{-12}, \quad -\psi_0 = 23.1 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 8.4 \times 10^{-4}.$$

After improvement, a run was made which was somewhat poorer than usual, with variations larger than the average, and values of ψ_0 determined at the two temperatures differing by about twenty percent. The constants are

$$-\kappa_0 = 5.08 \times 10^{-12}, \quad -\psi_0 = 25.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 7.1 \times 10^{-4},$$

in good agreement with the previous results. As final values, I take the compressibility and change with pressure from this run, and 7.5×10^{-4} for the temperature coefficient. Richards's corrected value is 5.27×10^{-12}, in fair agreement with this result.

KF. This salt, again a difficult one, was from Eimer and Amend, and stated to have very small impurities. Its melting point is high, and this made the process of crystallization rather difficult. A good sample was obtained, however. A rough preliminary run, made to test the pressure apparatus, gave a result agreeing closely with that of the final run. The relative variations were naturally large. The change of compressibility with pressure at the two temperatures agreed exactly. The final values are

$$-\kappa_0 = 3.31 \times 10^{-12}, \quad -\psi_0 = 20.1 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 1.2 \times 10^{-4}.$$

KCl. The salt was from stock, and was originally from Merck. It was easily crystallized, and one melt yielded a large amount of usable material. More readings were made on this substance than on any other; it was used in testing the apparatus before the improvement, to try to locate the source of error. Readings were made on four samples, and in some cases several runs were made on a single sample. The results obtained before the improvement of the apparatus were

$-\kappa_0$	$-\psi_0$	$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p$
5.58×10^{-12}	24.4×10^{-12}	
5.49	23.3	
5.57	24.4	5.1×10^{-4}
5.75	28.8	
5.74	27.7	
5.68	27.1	
5.63	26.1	
5.60	25.3	4.5
5.79	31.1	

The list gives a good idea of the range of variation of the constants before the improvement of the apparatus. The average of these results is

$$-\kappa_0 = 5.65 \times 10^{-12}, \quad -\psi_0 = 26.4 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 4.8 \times 10^{-4}.$$

After the improvement, readings were made on two samples, which previously had given results far apart. The values are

$$-\kappa_0 = 5.62 \times 10^{-12}, \quad -\psi_0 = 26.2 \times 10^{-12},$$

and

$$5.63 \qquad\qquad 26.7.$$

These are seen to be in good agreement with each other, and with the mean of the previous results. No readings were made on the temperature coefficient after improvement. The final results are taken to be

$$-\kappa_0 = 5.63 \times 10^{-12}, \quad -\psi_0 = 26.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 4.8 \times 10^{-4}.$$

The compressibility is, I believe, correct to three or four tenths of a percent, and the change of compressibility with pressure to less than two percent. It is thus known more accurately than for any other salt. Richards's result is 5.22×10^{-12}, and seems to be plainly too low. The value of Madelung and Fuchs is 5.62×10^{-12}, in very good agreement with the figure above.

KBr. This was the first salt crystallized; good samples were obtained. Before the improvement of the apparatus, runs on two separate samples gave

$$-\kappa_0 = 6.70 \times 10^{-12}, \quad -\psi_0 = 32.0 \times 10^{-12},$$

$$6.58 \times 10^{-12} \qquad\qquad 29.2 \times 10^{-12}$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 9.8 \times 10^{-4}$$

$$4.3 \times 10^{-4}$$

After improvement, a run was made, with somewhat larger variation than ordinarily, the separate curves giving about ten percent difference between the values of ψ_0 at the two temperatures; the values are

$$-\kappa_0 = 6.75 \times 10^{-12}, \quad -\psi_0 = 31.9 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 5.5 \times 10^{-4}.$$

As final, I take

$$-\kappa_0 = 6.70 \times 10^{-12}, \quad -\psi_0 = 31.8 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.0 \times 10^{-4}.$$

Richards's value for the compressibility is 6.42×10^{-12}, again somewhat lower.

KI. This salt was obtained from stock, and was extremely easy to crystallize. There were no indications of decomposition. Before improvement, two runs were made which gave very discordant values, and values which did not seem to be anywhere near what they should be. It was these runs that led me to investigate the errors in the apparatus. After improvement, two separate runs were made on the same sample, giving

$$-\kappa_0 = 8.53 \times 10^{-12}, \quad -\psi_0 = 38.4 \times 10^{-12},$$

and

$$8.50 \qquad\qquad 39.7.$$

These runs were the first ones made after the improvement. Another run was made, the last run on any sample, quite a while after this. It gave

$$-\kappa_0 = 8.59 \times 10^{-12}, \quad -\psi_0 = 39.1 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.0 \times 10^{-4}.$$

The agreement between the runs, with a considerable time interval between them, is very satisfactory. As final, I take

$$-\kappa_0 = 8.54 \times 10^{-12}, \quad -\psi_0 = 39.1 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.0 \times 10^{-4}.$$

Professor Richards's value is 8.8×10^{-12}.

RbBr. This salt was obtained from Eimer and Amend, and was stated to be pure. It was crystallized fairly satisfactorily; no single crystal large enough to make a sample could be found, however, and it was necessary to make one from a blank with a joint between crystals in it. On account of the softness it was possible to turn it without breaking, and the resulting sample seemed to be satisfactory. It was found that this salt has a polymorphic transition under pressure. The band of indifference about the transition point is about two thousand atmospheres wide, so that no accurate measurement of the transition pressure was possible. Neither could an accurate measurement of the change of volume be found, since when a solid suffers a transition under pressure, its shape is likely to be distorted; as a matter of fact during the last run made on the sample, its diameter increased about

six thousandths of an inch, making it stick in the sleeve, and of course disturbing the readings. The transition point was approximately five thousand atmospheres, and varied very little with temperature; if anything, it was displaced slightly to higher pressure at high temperature. The change of volume was rather large, and appeared to be about six percent. The first time runs were made on the sample, before it was known that it had a transition, only three points were obtained before the change occurred; the change of volume was so large that the lever came to the end of its motion. When the pressure was released, the zero point returned a little beyond its original position—something that never occurred for any salt which had no transition. This was then repeated at 75°. The next day the sample was taken out, found to be opaque but not much distorted, and was put in with a larger steel base, so as to have, more chance for motion, and the run repeated. This time, the change of length on transition was not more than half what it had been the day before; the value of the initial compressibility was about the same, but the change of compressibility with pressure was about thirty or forty percent smaller. The smaller value is nearer what would be expected to be correct, and for this reason I adopt it. (This is the only case where I have discriminated between runs on account of what I thought the answer ought to be). On this second run, a good value for the compressibility of the high pressure modification was found. At the end of this run, the change of length coming down was greater than going up, about the same as the day before; but after the sample was taken out, it was found to have increased decidedly in diameter. The results on this substance, of course, had to be obtained in a range of pressure less than half the ordinary one in extent. For this reason, and also because undoubtedly the transition introduced mechanical imperfections into the sample, the results may be expected to have larger errors than the previous ones. For the low pressure phase, I find

$$-\kappa_0 = 7.94 \times 10^{-12}, \quad -\psi_0 = 35 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 1.7 \times 10^{-4}.$$

Richards and Saerens found 8.2×10^{-12} for $-\kappa_0$. For the high pressure phase, the results being extrapolated so as to refer to a normal state at zero pressure, the constants are

$$-\kappa_0 = 5.7 \times 10^{-12}, \quad -\psi_0 = 16 \times 10^{-12},$$

much smaller than for the other. The high pressure calculations rest on the assumption that the high pressure modification is cubic. It is to be presumed that this second phase is a body centered cubic modification, of the same crystal structure as RbF, and as the caesium salts with the exception of the fluoride. This is a structure of smaller volume, and would be expected to be formed at high pressure.

RbI. This was also from Eimer and Amend, and was the easiest salt of all to crystallize. It likewise has a polymorphic transition at apparently very nearly the same place as for RbBr, and of the same nature. A number of points were taken going up before the transition had taken place, and the sample was made larger than usual, so as to get a good value of the compressibility of the low pressure phase. The curve was fairly good, and the results should be fairly reliable. The constants are

$$-\kappa_0 = 9.62 \times 10^{-12}, \quad -\psi_0 = 43.6 \times 10^{-12}.$$

This sample was so long that the transition produced a change of length beyond the capacity of the apparatus. A second sample, about half the length, was made, and readings made at both temperatures before the transition occurred, keeping the pressure below the transition pressure. This gave

$$-\kappa_0 = 9.54 \times 10^{-12}, \quad -\psi_0 = 42.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.8 \times 10^{-4},$$

in satisfactory agreement with the other sample. As final values for the low pressure phase, I take

$$-\kappa_0 = 9.58 \times 10^{-12}, \quad -\psi_0 = 43.0 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.8 \times 10^{-4}.$$

The value of Richards and Saerens is 9.3×10^{-12}. The pressure was then increased beyond the transition, and measurements were made on the high pressure phase. The change of volume was apparently about eleven percent at the transition. The constants of the high pressure phase, extrapolated to refer to an initial state at zero pressure, were

$$-\kappa_0 = 9.6 \times 10^{-12}, \quad -\psi_0 = 58 \times 10^{-12}.$$

The fact that here the compressibility and its change with pressure

come out as large for the high pressure phase as for the low pressure one, while with RbBr they were much smaller for the high pressure phase, seems to throw doubt on the measurements for the high pressure phase for both salts. The constants could be determined with fair accuracy from the curves; but the sample may well have been distorted during the transition, and may not have given the true value of the compressibility. The method is not well suited for studying polymorphic transitions.

A table will now be given containing the values of these constants. As before, the compressibilities and change of compressibility with pressure are in reciprocal dynes per square centimeter, and the change of compressibility with temperature is in reciprocal degrees centigrade.

Salt	$-10^{12}\kappa_0$	$-10^{12}\psi_0$	$10^4 \frac{1}{\kappa_0}\left(\frac{\partial\kappa}{\partial T}\right)_p$
LiF	1.53	11.7	1.9
LiCl	3.41	19.8	6.9
LiBr	4.31	24.5	8.4
NaCl	4.20	21.9	6.8
NaBr	5.08	25.5	7.5
KF	3.31	20 1	1 2
KCl	5.63	26.5	4.8
KBr	6.70	31.8	6.0
KI	8.54	39.1	6.0
RbBr	7.94	35	1.7
RbI	9.58	43.0	6.8

Jefferson Physical Laboratory,
Harvard University.

Proceedings of the American Academy of Arts and Sciences.

Vol. 61. No. 6.—May, 1926.

CONTRIBUTIONS TO MINERALOGY FROM THE DEPARTMENT OF MINERALOGY AND PETROGRAPHY HARVARD UNIVERSITY

12. Catalogue of the Collection of Meteorites in the Mineralogical Museum of Harvard University

Charles Palache

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CHARLES PALACHE

Introduction

The collection of meteorites in the Mineralogical Museum of Harvard University was begun by the efforts of Professor J. P. Cooke and became important through the acquisition of the J. Lawrence Smith Collection in 1883. It was increased thereafter by gifts from Professor Cooke up to the time of his death in 1894, and then by exchange and by gifts from Professor J. E. Wolff, Cooke's successor as Curator of the Museum. A new period of growth began with the acquisition by the University of the Albert F. Holden bequest for the Museum in 1922.

The only catalogue of the collection hitherto published was prepared in 1887 by Dr. O. W. Huntington.[1] This catalogue was arranged by the date of fall or discovery of the meteorite and included all known up to that time. Each received a serial number and no sort of classification was attempted. The descriptions of the individual specimens were extended in the case of those irons particularly studied by Dr. Huntington who made a specialty of the structure of the iron meteorites.

In the following list which shows the present extent of the collection this arrangement has been abandoned for an alphabetic one following the example of the excellent Catalogue of Meteorites by G. T. Prior, published in 1923 for the British Museum Collection. In view of the completeness of this Catalogue with respect to all known falls, it seemed unnecessary to give detailed descriptions of the Harvard specimens. The numbers assigned by Huntington to the falls listed by him have, however, been retained and later acquisitions are indicated simply by a serial number. A symbol is introduced after the class name of each to show the place of the fall in the classification of Brezina.

The collection contains at present representatives of 351 falls with a total weight of 1,657 kilograms. Important additions within the

[1] Catalogue of all recorded Meteorites with a description of the Specimens in the Harvard College Collections. Proc. Am. Acad. Arts and Sciences 23, 1887, 37–110.

last decade include a very fine mass of the Mukerop (Bethany) Iron from South Africa of 232 kilograms; and the principal masses or large portions of the following falls:—Avoca, Texas, stone; Britstown, Cape Colony, iron; Cumpas, Mexico, iron; Gun Creek, Arizona, iron; Mount Ouray, Colorado, iron; New Baltimore, Pennsylvania, iron; Ollague, Bolivia, pallasite; Sierra Sandon, Chile, iron; and Ticraco Creek, West Australia, iron.

No. in Cat.	Date of fall or finding		Class		Locality	Weight in grams	
						Largest mass	Total
24	Ante	1780	Iron	Om	Adargas, Mexico	3.	3
478	Found	1881	Pallasite	Pr	Admire. Kansas	136.	409.
74	Fell	1814	Stone	Cia	Agen, France	9.	15.
479	Found	1909	Pallasite	P	Ahumada, Mexico	48.	48.
459	Found	1907	Iron	Ogg	Ainsworth, Nebraska	275.	371.
49	Fell	1806	Stone	K	Alais, France	6.	6.
125	Fell	1835	Stone	Cga	Aldsworth, England	9.	9.
136	Fell	1838	Stone	Cgb	Akbarpur, India	7.	7.
258	Fell	1860	Stone	Cga	Alessandria, Italy	6.	6.
412	Fell	1883	Stone	Ci	Alfianello, Italy	726.	726
480	Fell	1899	Stone	Cco	Allegan, Michigan	240.	301.
1	Ante	1884	Pallasite	Pk	Anderson, Ohio-Mound 4	181.	327.
2	Ante	1884	Pallasite ?	Pk	Anderson, Ohio-Mound 3	526.	754.*
519	Found	1919	Stone	Cg	Anthony, Kansas	118.	118.
38	Fell	1803	Stone	Cga	Apt, France	120.	120.
481	Found	1896	Iron	Ogg	Arispe, Mexico	570.	570.
428	Fell	1886	Stone	Cc	Assisi, Italy	3.	3.
311	Found	1867	Iron	H	Auburn, Alabama	20.	20.
297	Fell	1865	Stone	Cwa	Aumale, Algeria	15.	15.
156	Fell	1842	Stone	Cwa	Aumieres, France	2.	4.
394	Found	1880	Pallasite	P	Australia	90.	90.
245	Fell	1858	Stone	Cc	Aussun, France	210.	313.
531	Found	1924	Stone		Avoca, Texas	7,157.	7,620.
78	Found	1842	Iron	Db	Babb's Mill, Tennessee	795.	1,024.
73	Fell	1814	Stone	Cw	Bachmut, Ukraine	2.	2.
482	Found	1892	Iron	Off	Ballinoo, West Australia	2,278.	2,278.
342	Fell	1871	Stone	Am	Bandong, Java	.87	87
27	Fell	1790	Stone	Cga	Barbotan, France	10.	12.
303	Found	1855	Iron	Ob	Baranca Blanca, Chile	27.	27.
445	Fell	1892	Stone	Ccb	Bath, South Dakota	2,265	2,265
299	Found	1866	Iron	Of	Bear Creek, Colorado	38.	38.
446	Fell	1893	Stone	Cck	Beaver Creek, Brit. Col.	440.	440
434	Known	1888	Iron	Of	Bella Roca, Mexico	1,925.	1,925
23	Found	1784	Iron	Og	Bendego, Brazil	652.	666
65	Fell	1811	Stone	Cia	Berlanguillas, Spain	2	3.
466	Ante	1836	Iron	Of	Bethany, South Africa	232,305.	236,671
433	Fell	1887	Stone	Cca	Bielokrynitschie, Ukraine	5.	9
483	Found	1903	Iron	Og	Billings, Missouri	531.	531
159	Fell	1843	Stone	Bu	Bishopville, So. Carolina	48.	55
36	Ante	1805	Pallasite	Pa	Bitburg, Rhenish Prussia	252.	252

No. in Cat.	Date of fall or finding		Class		Locality	Weight in grams: Largest mass	Weight in grams: Total
452	Fell	1899	Stone	Cc	Bjurböle, Finland	568.	568
381	Found	1878	Stone	Ckb	Bluff, Texas	8,040.	8,040.
109	Found	1829	Iron	Og	Bohumilitz, Bohemia	49.	49.
54	Fell	1808	Stone	Cho	Borgo San Donnino, Italy	.5	5
58	Found	1810	Stone	Pr	Brahin, Russia	35.	35
220	Fell	1855	Stone	Ccb	Bremervorde, Germany		3.
180	Fell	1847	Iron	H	Braunau, Bohemia	32.	105.
425	Found	1882	Pallasite	Pa	Brenham, Kansas	51,900.	56,396.'
527	Ante	1915	Iron	Off	Britstown, Cape Colony	469.5	493 4
82	Ante	1819	Iron	Om	Burlington, New York	17.1	17 1
281	Fell	1863	Stone	Cwa	Buschhof, Latvia	22.	22.
201	Fell	1852	Stone	Bu	Bustee, India	3.	6.
354	Ante	1874	Iron	Off	Butler, Missouri	8,028.	14,179
356	Found	1874	Iron	Om	Cachiyuyal, Chile		2
77	Found	1818	Iron	Of	Cambria, New York	444.	692.
309	Fell	1866	Stone	Cgb	Cangas de Onis, Spain	779.	786
440	Found	1891	Iron	Og	Cañon Diablo, Arizona	70,100.	79,095.
520	Found	1894	Iron	Om	Canton, Georgia	122.	122
484	Found	1875	Iron	Om	Canyon City, California	321.	321.
29	Found	1793	Iron	Dc	Cape of Good Hope, S. Afr.	110.	110
430	Found	1887	Iron	Of	Carlton, Texas	3,284.	3,284
144	Found	1840	Iron	Om	Carthage, Tennessee	9,980.	12,192
518	Found	1867	Iron	Om	Casas Grandes, Mexico	1,860.	1,860
373	Known	1877	Iron	Og	Casey County, Kentucky	107.	240
357	Fell	1874	Stone	Cgb	Castalia, No. Carolina	211.	248
181	Fell	1848	Stone	Cwa	Castine, Maine	.5	5
137	Fell	1838	Stone	Cib	Chandakapur, India	15.	15
68	Fell	1812	Stone	Cgb	Chantonnay, France	43.	43.
40	Known	1804	Iron	Om	Charcas, Mexico	37.	51.
124	Fell	1835	Iron	Of	Charlotte, Tennessee	1,975.	2,188.
121	Fell	1834	Stone	Ci	Charwallas, India		1 5
63	Fell	1810	Stone	Cga	Charsonville, France	30.	31
76	Fell	1815	Stone	Cha	Chassigny, France		3
154	Fell	1841	Stone	Cia	Chateau-Renard, France	44	80
177	Ante	1849	Iron	Dl	Chesterville, So. Carolina	24.	24
530	Known	1881	Iron	Om	Chilkoot, Alaska	155.	155.
485	Found	1902	Iron	Om	Chinautla, Central Am.	95.	95
349	Found	1873	Iron	Om	Chulafinnee, Alabama	103.	159.
26	Found	1852	Iron	Of	Chupaderos, Mexico	95.	95.
261	Found	1860	Iron	Om	Cleveland, Tennessee	21.	21
132	Known	1837	Iron	H	Coahuila, Mexico	317,500.	819,200
407	Known	1837	Iron	H	Coahuila (Fort Duncan)	331.	387.
107	Known	1837	Iron	H	Coahuila (Sancha Estate)	820.	904.
410	Fell	1917	Stone	Cia	Colby, Wisconsin	83.	83.
139	Fell	1838	Stone	K	Cold Bokkeveld, So. Af.	5.	14.
486	Found	1880	Iron	Om	Colfax, No. Carolina	176.	176.
487	Found	1913	Iron	Og	Cookeville, Tennessee	79.	79
254	Known	1860	Iron	Om	Coopertown, Tennessee	1,300.	2,094.
290	Found	1863	Iron	Obc	Copiapo, Chile	320.	333
143	Known	1837	Iron	Og	Cosby's Creek, Tenn.	12,075.	21,750
488	Found	1881	Iron	Om	Costilla Peak, N. Mexico	1,551	1,551

No. in Cat.	Date of fall or finding		Class		Locality	Weight in grams	
						Largest mass	Total
421	Found	1887	Stony-iron	M	Crab Orchard Mts., Tenn.	670.	670.
197	Found	1852	Iron	Of	Cranberry Plains, Va.	16.	30.
214	Found	1854	Iron	Og	Cranbourne, Australia	686.	1,180.
444	Fell	1892	Stone	Cg	Cross Roads, No. Carolina	9.	9.
521	Found	1911	Stone	Cc	Cullison, Kansas	18.	18.
477	Fell	1919	Stone	Wht	Cumberland Falls, Ken.	154.	154.
457	Found	1903	Iron	Om	Cumpas, Mexico	24,168.	25,143.
377	Fell	1877	Stone	Cg	Cynthiana, Kentucky	3,113.	3,118.
372	Found	1877	Iron	Om	Dalton, Georgia	202.	439
319	Fell	1868	Stone	Ck	Daniel's Kuil, So. Africa	22.	22.
325	Fell	1868	Stone	Cga	Danville, Alabama	84.	84.
175	Found	1846	Iron	Db	Deep Springs, No. Carolina	111.	111.
223	Known	1856	Iron	Om	Denton County, Texas	49.	49.
416	Found	1780	Iron	Om	Descubridora, Mexico	1,298.	1,335.
262	Fell	1860	Stone	Ci	Dhurmsala, India	540.	543.
413	Fell	1884	Stone	Ck	Djati-Pengilon, Java	270.	270.
105	Fell	1827	Stone	Cwa	Drake Creek, Tennessee	1,200.	1,310.
209	Found	1854	Iron	Of	Duel Hill (1854) No. Car.	106.	140.
351	Found	1873	Iron	Og	Duel Hill (1873) No. Car.	222.	246.
75	Fell	1815	Stone	Cia	Durala, India	20.	36.
208	Fell	1853	Stone	Cia	Duruma, East Africa	1.	1.
397	Found	1880	Pallasite	P	Eagle Station, Kentucky	26.	51.
273	Known	1862	Iron	Og	Ehrenberg, Arizona	49.	49.
4	Fell	?1400	Iron	Om	Elbogen, Bohemia	147.	170.
490	Found	1893	Iron	Om	El Capitan, New Mexico	540.	540.
458	Found	1906	Stone	Cc	Elm Creek, Kansas	485.	493.
211	Found	1854	Iron	Om	Emmitsburg, Maryland	10.	10.
5	Fell	1492	Stone	Ckb	Ensisheim, France	22.	30.
491	Fell	1889	Stone	Ckb	Ergheo, East Africa	155.	155.
67	Fell	1812	Stone	Ck	Erxleben, Prussia	1.	1.
456	Found	1883	Stone	Cka	Estacado, Texas	17,800.	18,030.
390	Fell	1879	Stony-iron	M	Estherville, Iowa	12,600.	18,562.
439	Fell	1890	Stone	Csa	Farmington, Kansas	2,792.	3,216.
522	Fell	1900	Stone	Cc	Felix, Alabama	17.	17.
451	Found	1902	Pallasite	P	Finmarken, Arctic Norway	392.	401.
447	Fell	1894	Stone	Cia	Fisher, Minnesota	471.	471.
438	Fell	1890	Stone	Ccb	Forest City, Iowa	527.	968.
110	Fell	1829	Stone	Cwa	Forsyth, Georgia	56.	57.
492	Found	1891	Iron	Dn	Forsyth County, No. Car.	52.	52.
225	Found	1856	Iron	Om	Fort Pierre, So. Dakota	35.	63.
525	Ante	1924	Iron	Obc	Four Corners, New Mexico	1,600.	1,600.
493	Found	1890	Iron	Om	Franceville, Colorado	2,260.	2,260.
301	Found	1866	Iron	Om	Frankfort (iron) Kentucky	7,519.	7,519.
326	Fell	1868	Stone	Ho	Frankfort (stone) Alabama	106.	121.
91	Fell	1822	Stone	Cwa	Futtehpur, India	31.	53.
515	Found	1905	Stone	Cw	Garraf, Spain	185.	185.
494	Found	1889	Stone	Ck	Gilgoin Station, N. S. W.	223.	223.
206	Fell	1853	Stone	Cwa	Girgenti, Italy	14.	14.
414	Found	1884	Iron	Om	Glorieta Mt., New Mexico	546.	1,601.
316	Found	1868	Stone	U	Goalpara, India	40.	40.
266	Fell	1861	Stone	Cs	Grcsnaja, Caucasus	7.	7

No. in Cat.	Date of fall or finding		Class		Locality	Weight in grams	
						Largest mass	Total
409	Found	1883	Iron	Of	Grand Rapids, Michigan	1,010.	1,433.
464	Found	1909	Iron	O	Gun Greek, Arizona	16,813.	17,421.
227	Found	1856	Stony-iron	M	Hainholz, Germany	209.	334.
420	Found	1884	Iron	Oh	Hammond Tp., Wisconsin	83.	111.
249	Fell	1859	Stone	Cho	Harrison County, Ind.	76.	76.
500	Fell	1910	Stone	Cg	Hedjaz, Arabia	13.	21.
465	Found	1909	Stone	Cg	Hermitage Plains, N. S. W.	314.	314.
330	Fell	1869	Stone	Cc	Hessle, Sweden	368.	550.
468	Fell	1912	Stone	Cck	Holbrook, Arizona	2,520.	8,000.
361	Fell	1875	Stone	Cgb	Homestead, Iowa	5,425.	17,456.
99	Fell	1825	Stone	Cwa	Honolulu, Hawaiian Isles	30.	30.
12	Fell	1751	Iron	Om	Hraschina, Jugoslavia	6.	6.
454	Fell	1901	Stone	Ck	Hvittis, Finland	43.	43.
35	Known	1822	Pallasite	Pi	Imilac, Chile	187.	548.
395	Found	1880	Iron	Om	Ivanpah, California	336.	336.
437	Fell	1889	Stone	Am	Jelica, Serbia	35.	35.
402	Found	1883	Iron	Og	Jenny's Creek, W. Va.	31.	31.
352	Fell	1873	Stone	Cc	Jhung, India	44.	44.
241	Found	1858	Iron	Om	Joel's Iron, Chile	13.	13.
408	Fell	1924	Stone	Chl	Johnstown, Colorado	783.	808.
83	Fell	1819	Stone	Eu	Jonzac, France		.9
87	Fell	1812	Stone	Eu	Juvinas, France	71.	71.
236	Fell	1857	Stone	K	Kaba, Hungary	1.	1.
244	Fell	1858	Stone	Cga	Kakowa, Rumania	1.	1.
495	Known	1887	Iron	Hb	Kendall County, Texas	494.	494.
436	Found	1889	Iron	Om	Kenton County, Kentucky	3,856.	3,856.
332	Fell	1869	Stone	Cka	Kernouve, France	364.	398.
194	Fell	1850	Stone	Cc	Kesen, Japan	698.	698.
353	Fell	1873	Stone	Ck	Khairpur, India	66.	66.
467	Fell	1911	Stone	Cg	Kilbourn, Wisconsin	70.	70.
469	Found	1891	Iron	Om	Kingston, New Mexico	748.	748.
307	Fell	1866	Stone	Cg	Knyahinya, Czechoslovakia	533.	1,019.
269	Found	1862	Iron	Dc	Kokomo, Indiana	283.	377.
11	Found	1749	Pallasite	Pk	Krasnojarsk, Siberia	170.	225.
64	Fell	1811	Stone	Cwa	Kuleschovka, Ukraine	5.	5.
429	Fell	1886	Stone	Cwa	Kyushu, Japan.	32.	32.
37	Fell	1803	Stone	Cib	L'Aigle, France	90.	157.
6	Found	1828	Iron	Om	La Caille, France	304.	304.
255	Found	1860	Iron	Of	La Grange, Kentucky	196.	196.
347	Fell	1872	Stone	Kcc	Lancé, France	33.	33.
529	Fell	1907	Stone	Cgb	Leighton, Alabama	.7	.7
71	Found	1814	Iron	Om	Lenarto, Czechoslovakia	50.	119.
167	Fell	1845	Stone	Cc	Le Pressoir, France	3.	3
388	Found	1879	Iron	H	Lick Creek, No. Car.	6.	6.
69	Fell	1813	Stone	Cga	Limerick, Ireland	50.	50.
56	Fell	1808	Stone	Cwa	Lissa, Bohemia	6.	7.
142	Fell	1839	Stone	Cc	Little Piney, Missouri	8.	8.
86	Fell	1820	Stone	Cga	Lixna, Latvia	5.	5
496	Found	1857	Iron	Ds	Locust Grove, Georgia	93.	93.
441	Found	1891	Stone	Cia	Long Island. Kansas	340.	340
312	Found	1868	Iron	Om	Losttown, Georgia	13.	13

No. in Cat.	Date of fall or finding	Class	Locality	Weight in grams: Largest mass	Weight in grams: Total
334	Fell 1869	Stone Cck	Lumpkin, Georgia	45	53.
497	Fell 1889	Stone Cw	Lundsgard, Sweden	94.	94.
129	Fell 1836	Stone Cia	Macao, Brazil	17.	17.
212	Found 1854	Iron Of	Madoc, Canada	66.	81.
147	Found 1840	Iron Og	Magura, Czechoslovakia	208.	700.
191	Found 1852	Stone Cia	Mainz, Germany	5.	5.
285	Fell 1863	Stone Am	Manbhoom, India	4.	4.
179	Fell 1847	Stone Cwa	Marion, Iowa	203.	374.
453	Fell 1902	Pallasite P	Marjalahti, Finland	173.	173.
253	Found 1860	Iron Om	Marshall County, Ken.	71.	189.
18	Fell 1768	Stone Cw	Mauerkirchen, Upper Austria	9.	9.
34	Fell 1801	Stone Cho	Mauritius, Indian Ocean	1.	1.
498	Found 1870	Stone Cw	McKinney, Texas	594.	594.
514	Found 1905	Iron Dn	Mejillones, Chile	65.	65
267	Fell 1862	Stone Cc	Menow, Germany	91.	93.
415	Found 1884	Iron Om	Merceditas, Chile	1,589.	2,974.
502	Fell 1878	Stone Cka	Mern, Denmark	8	.S
199	Fell 1852	Stone Cgb	Mezö-Madaras, Transylvania	51.	69.
155	Fell 1842	Stone Cw	Milena, Jugoslavia	77.	77.
256	Found 1857	Stony-iron M	Mincy, Arkansas	104.	112
41	Known 1804	Iron Om	Misteca, Mexico	431.	488.
406	Fell 1882	Stone Cwa	Mocs, Transylvania	910.	1,347.
460	Fell 1905	Stone Cwa	Modoc, Kansas	147.	147.
246	Fell 1858	Stone Cgb	Molina, Spain	176.	176.
185	Fell 1849	Stone Cga	Monroe, No. Carolina	168.	179.
62	Fell 1810	Stone Cga	Mooresfort, Ireland	7.	7.
25	Known 1600	Iron Om	Morito, Mexico	35.	35.
327	Fell 1868	Stone Ck	Moti-ka-nagla, India	7.	7.
475	Found 1913	Iron Om	Mt. Edith, Western Australia	30,500.	30,500.
432	Found 1887	Iron Ogg	Mt. Joy, Penna.	568.	568.
462	Found 1898	Iron Om	Mt. Ouray, Colorado	626.	772.
442	Known 1892	Iron Og	Mt. Stirling, W. Australia	188.	188.
523	Known 1868	Pallasite P	Mt. Vernon, Kentucky	1,150.	1,150.
449	Found 1897	Iron Off	Mungindi, N. S. W.	31.	31.
176	Found 1847	Iron Om	Murfreesboro, Tenn.	1,480.	2,275.
499	Found 1899	Iron H	Murphy, No. Car.	213.	213.
489	Fell 1911	Stone Na	Nakhla, Egypt	88.	313.
98	Fell 1825	Stone Cc	Nanjemoy, Maryland	117.	123.
335	Fell 1870	Iron Dn	Nedagolla, India	20.	20.
226	Found 1856	Iron Ogg	Nelson County, Ken.	2,800.	2,800.
287	Fell 1864	Stone Cia	Nerft, Latvia	24.	24.
507	Found 1894	Stone Ck	Ness County, Kansas	683.	730.
526	Found 1922	Iron Og	New Baltimore, Penna.	10,400.	14,704.
260	Fell 1860	Stone Cia	New Concord, Ohio	23,030.	27,859.
93	Fell 1823	Stone Ho	Nobleborough, Maine	3.	3.
277	Known 1863	Iron Of	Obernkirchen, Germany	227.	387.
501	Fell 1887	Stone Ccb	Ochansk, Russia	22.	37.
238	Fell 1857	Stone Cga	Ohaba, Transylvania	26.	26.
472	Fell 1904	Iron H	Okano, Japan	383.	383.
210	Found 1854	Iron Db	Oktibbeha County, Miss.	3.	4.
424	Fell 1924	Stone Ci	Olivenza, Spain	157.	157.

No. in Cat.	Date of fall or finding		Class		Locality	Weight in grams: Largest mass	Total
512	Found	1923	Pallasite	P	Ollague, Bolivia	4,956.	5,485.
224	Known	1855	Iron	Om	Orange River, So. Africa	32.	32.
288	Fell	1864	Stone	K	Orgueil, France	15.	26.
322	Fell	1868	Stone	Cc	Ornans, France	2.	2.
448	Found	1895	Iron	Og	Oscuro Mtns., N. M.	57.	57.
20	Found	1783	Iron	Ds	Otumpa, Argentina	149.	149.
233	Fell	1857	Stone	Cga	Parnallee, India	277.	422.
102	Fell	1826	Stone	Cw	Pavlograd, Ukraine	134	134.
222	Fell	1855	Stone	Ho	Petersburg, Tenn.	5.	9.
282	Fell	1863	Stone	Ck	Pillistfer, Latvia	14.	14.
431	Found	1887	Stone	Cka	Pipe Creek, Texas	195.	294.
187	Found	1850	Iron	Ogg	Pittsburg, Penna.	34.	34.
524	Found	1917	Stone	Cia	Plainview, Texas	1,332.	1,332.
503	Found	1893	Iron	Om	Plymouth, Indiana	562.	562.
84	Fell	1918	Stone	Cwa	Pohlitz, Germany	3.	3
278	Found	1863	Iron	Ogg	Ponca Creek, Nebraska	81.	81.
317	Fell	1868	Stone	Cga	Pultusk, Poland	689.	1,461.
411	Found	1885	Iron	Om	Puquios, Chile	208	208.
141	Found	1839	Iron	Of	Putnam County, Gecrgia	2,112.	2,311.
239	Fell	1857	Stone	Cc	Quenggouk, Lower Burma	85.	87.
42	Found	1882	Iron	Om	Rancho de la Pila, Mexico	42.	42.
53	Found	1808	Iron	Om	Red River, Texas	1,740.	1,762.
471	Found	1895	Iron	Og	Reed City, Michigan	490.	490.
95	Fell	1824	Stone	Cs	Renazzo, Italy	34.	68.
504	Fell	1918	Stone	Cca	Richardton, No. Dakota	2,943.	3,164.
108	Fell	1828	Stone	Cck	Richmond, Virginia	3.	5.
371	Fell	1876	Stone	Cc	Rochester, Indiana	75.	75.
528	Found	1852	Iron	Of	Rodeo, Mexico	1,732.	1,732.
443	Found	1892	Stone	Om	Roebourne, W. Australia	560.	560.
505	Found	1896	Iron	Og	Rosario, Honduras	3.	3.
368	Fell	1876	Iron	Om	Rowton, England	17.	17.
186	Found	1844	Iron	Om	Ruff's Mtn., So. Car.	448.	575.
517	Found	1866	Stone	Cgb	Rushville, Indiana	7.	7.
279	Found	1863	Iron	Of	Russel Gulch, Colorado	1,624.	1,771.
506	Found	1896	Iron	Om	Sacramento Mtns., N. M.	1,235.	1,304.
275	Ante	1863	Iron	Og	St. Francois Co , Missouri	29.	48.
510	Fell	1890	Stone	Cc	St. Germain-en-Puel, France	5	5.
306	Fell	1866	Stone	Cib	St. Mesmin, France	3.	4.
470	Fell	1910	Stone	Cw	St. Michel, Finland	598	598.
33	Fell	1798	Stone	Cia	Salles, France	6.	6.
188	Found	1850	Iron	Off	Salt River, Kentucky	304.	304.
473	Found	1894	Iron	Om	Sams Valley, Oregon	1,160.	1,160.
450	Found	1897	Iron	Om	San Angelo, Texas	295.	295.
310	Ante	1868	Iron	Ds	San Francisco del Mezquital, Mexico	52.	52.
360	Found	1875	Iron	Dn	Santa Catharina, Brazil	917.	3,767.
59	Found	1810	Iron	Ds	Santa Rosa, So America	4.	8.
508	Ante	1883	Iron	Hb	Sao Juliao de Moreira, Portugal	809.	814.
216	Found	1854	Iron	Og	Sare.ta, Russia	446.	446.
323	Fell	1868	Stone	Cwa	Sauguis, France	6.	6

No. in Cat.	Date of fall or finding		Class		Locality	Weight in grams	
						Largest mass	Total
189	Found	1850	Iron	Om	Schwetz, Poland	31.	31.
509	Found	1905	Stone	Cc	Scott City, Kansas	155.	155
315	Found	1867	Iron	H	Scottsville, Kentucky	534.	555.
341	Fell	1871	Stone	Cc	Searsmont, Maine	20.	50.
178	Ante	1847	Iron	Ogg	Seelasgen, Prussia	706.	954
207	Fell	1853	Stone	Ck	Segowlie, India	118.	118.
190	Found	1850	Iron	Om	Seneca Falls, New York	10.	10
80	Fell	1818	Stone	Cg	Seres, Macedonia	19.	19.
192	Fell	1850	Stone	Chl	Shalka, India	3.	3.
455	Fell	1904	Stone	Cga	Shelburne, Canada	492.	492.
463	Found	1907	Iron	Om	Shrewsbury, Penna.	508.	508.
283	Fell	1863	Stone	Cib	Shytal, India	2.	2.
30	Fell	1794	Stone	Cho	Siena, Italy	5.	5.
513	Ante	1923	Iron	Cg	Sierra Sandon, Chile	6,326.	6,326.
15	Found	1816	Iron	Ds	Siratik, West Africa	22.	22.
362	Fell	1875	Stone	Cho	Sitathali, India	14.	14.
81	Fell	1818	Stone	Cc	Slobodka, Russia	4.	4.
148	Found	1839	Iron	Db	Smithland, Kentucky	1,330.	1,879.
276	Found	1863	Iron	Of	Smith's Mtn., No. Carolina	467.	816.
146	Found	1840	Iron	Og	Smithville, Tennessee	2,240.	3,303.
380	Fell	1877	Stone	Cc	Soko-Banja, Serbia	196.	240.
370	Fell	1876	Stone	Cgb	Ställdalen, Sweden	78.	78.
55	Fell	1808	Stone	Eu	Stannern, Czechoslovakia	183.	221.
242	Found	1858	Iron	Om	Staunton, Virginia	2,740.	4,595
3	Found	1724	Stony-iron	Si	Steinbach, Saxony	225.	585.
292	Fell	1865	Stone	Cgb	Supuhee, India	33	33.
13	Fell	1753	Stone	Ccb	Tabor, Bohemia	14.	14.
314	Fell	1867	Stone	Ct	Tadjera, Algeria	27.	27.
203	Found	1853	Iron	Off	Tazewell, Tennessee	381.	720.
427	Known	1886	Iron	Om	Thunda, Queensland	51.	51.
532	Found	1922	Iron	Om	Ticraco Cr., West Australia	21,950.	21,950.
382	Fell	1878	Stone	Cc	Tieschitz, Czechoslovakia	7.	15.
50	Fell	1807	Stone	Cc	Timochin, Russia	7.	7.
22	Ante	1776	Iron	Om	Toluca, Mexico	18,370.	35,210.
474	Found	1859	Iron	D	Tombigbee River, Alabama	98.	98.
286	Found	1863	Stone	Cgb	Tomhannock Creek, N. Y.	12.	12.
392	Fell	1879	Stone	Cc	Tomatlan, Mexico	1.	1.
426	Found	1886	Iron	Om	Tonganoxie, Kansas	220.	220.
511	Found	1891	Iron	Om	Toubil River, Siberia	41.	41.
284	Fell	1863	Stone	Cw	Tourinnes-la-Grosse, Belgium	11.	11.
243	Found	1858	Iron	Om	Trenton, Wisconsin	3,630.	6,350.
231	Fell	1856	Stone	Cca	Trenzano, Italy	151.	151.
193	Ante	1850	Iron	Dm	Tucson, Arizona	599.	1,161.
304	Fell	1866	Stone	Cga	Udipi, India	31.	57.
204	Found	1853	Iron	Ogg	Union County, Georgia	24	35
160	Fell	1843	Stone	Cca	Utrecht, Holland	6	6.
271	Known	1861	Stony-iron	M	Vaca Muerta, Chile	275.	774.
399	Fell	1880	Stony-iron	M	Veramin, Persia	9.	9.
213	Found	1854	Iron	Om	Verkhne Udinsk, Siberia	46.	46.
293	Fell	1865	Stone	Cka	Vernon County, Wisconsin	100.	148.
268	Fell	1860	Iron	Of	Victoria West, So. Af.	143.	191.

No. in Cat.	Date of fall or finding		Class		Locality	Weight in grams	
						Largest mass	Total
533	Fell	1910	Stone	Cks	Vigarano. Italy	32.	32.
114	Fell	1831	Stone	Cia	Vouille, France	103.	103.
344	Found	1873	Stone	Ccb	Waconda, Kansas	1,675.	3,256.
422	Known	1887	Iron	Og	Waldron Ridge, Tennessee	12.	12.
116	Found	1832	Iron	H	Walker County, Ala.	1,890.	2,307.
376	Fell	1877	Stone	Cco	Warrenton, Missouri	242.	487.
435	Found	1888	Iron	Om	Welland, Canada	138.	138.
51	Fell	1807	Stone	Ccb	Weston, Connecticut	135.	223.
127	Ante	1836	Iron	Og	Wichita County, Texas	1,800	1,800.
461	Found	1892	Iron	Om	Williamstown, Kentucky	380.	380.
31	Fell	1795	Stone	Cwa	Wold Cottage, England	65.	66.
240	Known	1858	Iron	Om	Wooster, Ohio	3.	6.
198	Fell	1852	Stone	Cc	Yatoor, India	58	88.
418	Fcund	1884	Iron	Og	Youndegin, W. Australia	623	623.
79	Fell	1818	Stone	Cia	Zaborzika, Ukraine	5	5.
28	Ante	1792	Iron	Obz	Zacatecas, Mexico	143.	281
516	Fell	1897	Stone	Cgb	Zavid, Jugoslavia	46.	46.

Proceedings of the American Academy of Arts and Sciences.

Vol. 61. No. 7 June, 1926.

A MATHEMATICAL STUDY OF CRYSTAL SYMMETRY

By Austin F. Rogers

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CONTENTS

Introduction.

The modern classification of crystals is based primarily upon symmetry. The types of symmetry possible in crystals are now firmly established. As early as 1830, Hessel predicted the existence of the 32 crystal classes when representatives of only 17 of the 32 were known. Hessel's work was overlooked for many years, but was confirmed by later investigators. At the present time examples of all but one (the trigonal bipyramidal class) of the 32 possible crystal classes have been found, either among minerals or products of the laboratory.

Although the various types of crystal symmetry are now well established, there is a decided lack of uniformity in the manner of expressing the symmetry. Some authors emphasize planes of symmetry while others emphasize axes of symmetry. Many authorities disregard the center of symmetry. Some writers use rotatory-reflections as symmetry operations, while a few employ rotatory-inversions instead. There is, indeed, a marked difference of opinion as to what constitutes the true elements of symmetry.

This paper is presented with the conviction that a mathematical treatment of the subject will settle the disputed points and enable us

to determine what the true symmetry elements are. If any subject in the whole realm of science is capable of mathematical treatment, it would seem that crystal symmetry is, for in crystals we find Nature in her most mathematical mood.

One of the points of contention is the use of the center of symmetry. The center of symmetry was included by Bravais in his classic paper,[1] which was the first serious contribution to the study of crystal symmetry. But it has been contended by Fedorov, Groth, and others that the center of symmetry is not a true element of symmetry. By appeal to the mathematical theory of groups the writer has been able to settle this question definitely. The consideration of the center of symmetry led to a thorough study of all the other possible elements of symmetry.

Symmetry Operations

In a critical study of symmetry it has been found convenient to use the term *operation*, which may be defined as a movement of some kind which brings a polyhedron into coincidence either with itself or its mirror image. The only movements or operations that concern us here are those that leave the center of the figure unmoved.

In a discussion of crystal symmetry it is customary to deal only with faces of the general form, that is, with *hkl* faces or those which are neither parallel nor perpendicular to axes or planes of symmetry. A further advantage in our study is gained if we consider the operations necessary to derive all the faces of a general form from a single initial face. This method furnishes the key to the solution of the problem before us. Let us now consider the various symmetry operations possible in crystals.

Rotation about an Axis. Since the possible axes of symmetry in crystals are restricted to 2-fold, 3-fold, 4-fold, and 6-fold, the angles of rotation are limited to the crystallometric angles 60°, 90°, 120°, 180°, 240°, 270°, and 300° (360° gives identity). These operations may be designated by the following symbols: a_{60°, a_{90°, a_{120°, a_{180°, a_{240°, a_{270°, and a_{300°. Throughout this article rotations are considered

[1] *Mémoire sur les polyèdres de forme symétrique*, *Jour. de Math.*, vol. 14, pp. 141–180, 1849. Reprinted in *Etudes Cristallographiques*, pp. xxi-lxii, Paris, 1866.

to be counter-clockwise. The operations are represented by Figs. 2–8.[2]

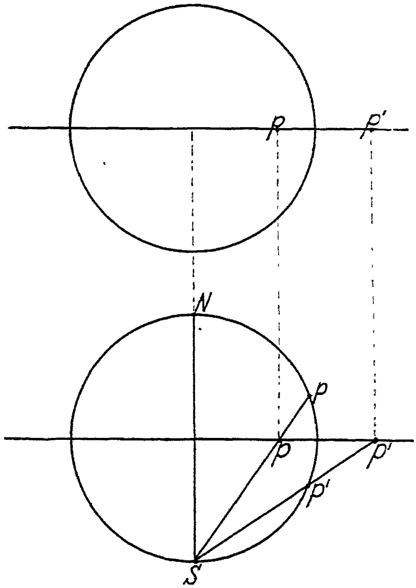

FIG. 1. Plan and elevation showing the method of plotting upper (p) and lower (p') faces on a stereographic projection.

Reflection in a Plane. This operation may be designated by the symbol p. It is represented by Fig. 9.

Wulff[3] has shown that all symmetry operations may be expressed in terms of planes of symmetry. Successive reflections in two planes of symmetry are equivalent to a rotation about an axis of symmetry.

[2] These and the following figures are stereographic projections. In these projections faces on the upper half of the crystal appear within the equatorial circle, while faces on the lower half of the crystal appear outside the equatorial circle. The accompanying figure (Fig. 1) shows the method of constructing the projections and the relation between the upper (p) and lower (p') faces. The angle Np equals the angle Sp'. In this method both projections are made from the south pole; in the usual method (first employed by Gadolin) projections for faces on the upper half of the crystal are made from the south pole and projections for faces on the lower half of the crystal are made from the north pole.

[3] *Zeit. f. Kryst. u. Min.*, vol. 27, pp. 556–558, 1897.

While this is true, it should be emphasized that the two virtual[4] planes of symmetry are situated at crystallometric angles to each other, which really means that rotation is the effective operation.

Becke,[5] on the other hand, has shown that it is possible to disregard planes of symmetry. He states that a rotatory-inversion[6] of 180° is equivalent to a reflection in a plane of symmetry. Now it is advisable at times to use a rotatory-inversion, but it is not necessary here, for reflection is a far simpler operation.

The simplest way of deriving an $(h\bar{k}l)$ face from the initial (hkl) face is by reflection in a plane (010).

Inversion about the Center. The operation of passing from the initial face (hkl) to the opposite parallel face $(\bar{h}\bar{k}\bar{l})$ is called *inversion.* It may be represented by the symbol c. Fig. 10 illustrates inversion.

The corresponding element of symmetry is a center of symmetry designated by C, a symbol first used by Bravais.[7]

Fedorov,[8] the Russian crystallographer, maintained that the center of symmetry is not a true element of symmetry, but simply the effect of a rotation of 180° about an axis, combined with reflection in a plane normal to the axis, that is, a particular case of rotatory-reflection. Fedorov has been followed by Groth,[9] Tutton,[10] Swartz,[11] Jellinek,[12] Oebbeke and Weinschenk,[13] and others. One gains the impression that some authors use the center of symmetry simply because of the difficulty involved in the operation of rotatory-reflection. Dana,[14] for example, says, " This method [he refers to rotatory-reflection] is not followed here since, though having certain theoretical advantages, it is likely to confuse the student meeting the problems of crystallog-

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[4] This term is used by Jaeger, *Lectures on the Principles of Symmetry*, 1st ed., p. 30, Amsterdam, 1917.

[5] *Zeit. f. Kryst. u. Min.*, vol. 25, pp. 73–78, 1896.

[6] This term is explained on page 168.

[7] Loc. cit., p. 141.

[8] *Verhandl. Russ. Min Ges.*, vol. 25, pp. 5–7, 1899. *Zeit. f. Kryst. u. Min.*, vol. 21, p. 586, 1893.

[9] *Lehrbuch der Physikalischen Krystallographie*, 4th ed., p. 329, Leipzig, 1905.

[10] *Crystallography and Practical Crystal Measurement*, 2nd ed., vol. 1. p. 128, p. 135, London, 1922.

[11] *Bull. Geol. Soc. Amer.*, vol. 20, pp. 384–5, 1909.

[12] *Lehrbuch der Physikalischen Chemie*, vol. 2, p. 414, Stuttgart, 1915.

[13] Von Kobell's *Lehrbuch der Mineralogie*, 6th ed., p. 17, Leipzig, 1899.

[14] *Text Book of Mineralogy*, 2nd ed., p. 10, 1898.

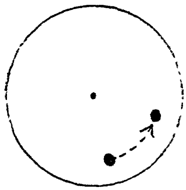


FIG. 2. $a_{60°}$

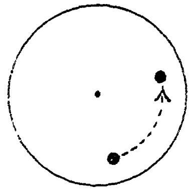


FIG. 3. $a_{90°}$

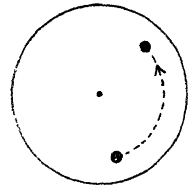


FIG. 4. $a_{120°}$

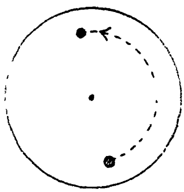


FIG. 5. $a_{180°}$

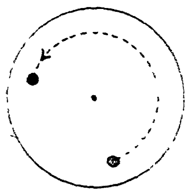


FIG. 6. $a_{240°}$

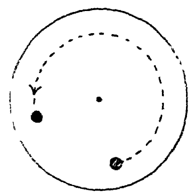


FIG. 7. $a_{270°}$

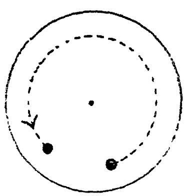


FIG. 8. $a_{300°}$

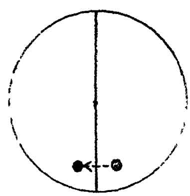


FIG. 9. p

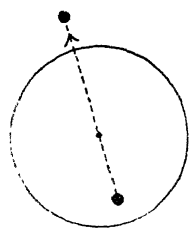


FIG 10 c

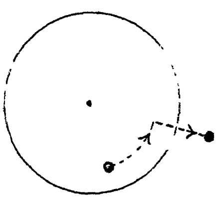


FIG. 11. $ap_{60°}$

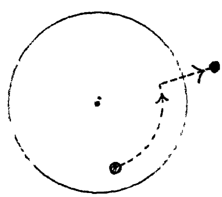


FIG. 12. $ap_{90°}$

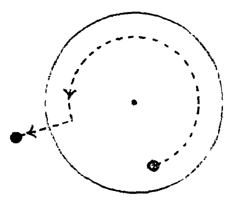
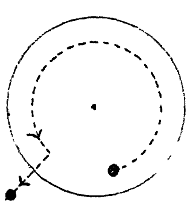
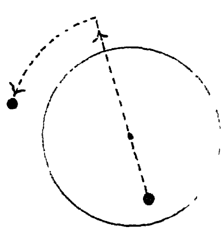
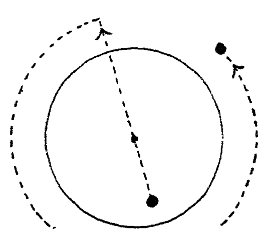


FIG. 13. $ap_{270°}$







raphy for the first time." While the idea of rotatory-reflection may be somewhat difficult for the beginning student to grasp, the validity of the center of symmetry as an element of symmetry should be decided solely upon its merits.

Some of those who discard the center of symmetry fail to realize that the two-fold axis and plane of composite symmetry may have any position whatever in the crystal. This point has been emphasized by Marshall.[15] An axis or plane of symmetry not fixed in direction is obviously an absurdity. Any line through the geometric center of the crystal is a 2-fold axis of rotatory-reflection, $\mathcal{A}P_2$. Hence the symmetry according to this method must be expressed by the symbol $\infty\ \mathcal{A}P_2$ or its equivalent. It is true that an $(\bar{h}\bar{k}\bar{l})$ face may be derived from the initial (hkl) face by a rotatory-reflection of 180°, but when we come to the elements of symmetry we have to write $\infty\ \mathcal{A}P_2$ in order to include all the possible symmetry operations. But an opposite, parallel face is derived from the initial face by a single operation and not by an infinitude of operations. This operation has been called *inversion*. Since the operation takes place about a point which is the geometric center of the crystal, the crystal is said to be symmetrical to a center. The intersection of an infinite number of lines (2-fold axes of rotatory-reflection) is a point, which is called the center of symmetry. Hence *the center of symmetry is a true element of symmetry.*

Another argument in favor of considering the center of symmetry as an element of symmetry is the existence of point-twinning as it has been termed by Evans.[16] This type of twinning was first mentioned by Bravais.[17] It has been overlooked by most writers, but has been emphasized by Evans. The best examples of point-twinning are the " Brazilian " twins of quartz. As the twin-crystal apparently has a center of symmetry, the twinning may be described as inversion-twinning or point-twinning. The two parts of the twin are symmetrical to a point. These quartz twins are usually described as being twinned on the $(11\bar{2}0)$ face, but in point-twinning every plane normal to an axis of even-fold symmetry has the characters of a twin-plane, and as Evans indicates, point-twinning is more important than plane-twinning that accompanies it.

[15] *Proc. Roy. Soc. Edinburgh*, vol. 25, I, pp. 383–4, 1904.

[16] *Mineral. Mag.*, vol. 15, p. 393, 1909; *ibid.* vol. 18, pp. 224–243, 1918.

[17] *Etudes Cristallographiques*, IIIme Partie pp. 258–9, Paris, 1866.

Eleven classes out of the 32 have a center of symmetry.

Rotatory-reflection with respect to a Plane and an Axis of Rotation normal thereto. There are operations which cannot be referred to either rotations, reflections, or inversions. On crystals of the tetragonal bisphenoidal class, for example, there are four faces in the general form. The initial face is (hkl); the $(\bar{h}\bar{k}l)$ face is produced by a rotation of 180°; the simplest way to obtain the other two faces, $(\bar{k}h\bar{l})$ and $(k\bar{h}\bar{l})$, is to combine a rotation of 90° and 270° respectively with a reflection in a plane normal to the axis of rotation. The combined effect of rotation and reflection is considered to be a single operation, called for convenience *rotatory-reflection.* It might be well to use the term *rotoflection* for this operation. The symbols used are $ap_{90°}$ (Fig. 12) and $ap_{270°}$ (Fig. 13). Compound symbols are used here since rotation and reflection taken together are effective operations. Besides these there are two other rotatory-reflections possible in crystals, $ap_{60°}$ (Fig. 11) ($hk\bar{i}l$ to $\bar{k}i\bar{h}\bar{l}$) and $ap_{300°}$ (Fig. 14) ($hk\bar{i}l$ to $i\bar{h}\bar{k}\bar{l}$). As has been shown on page 166 a rotatory-reflection of 180° is equivalent to a center of symmetry, and the point was made that the latter term must be used instead.

Although he discussed it, Bravais[18] failed to include the composite axis-plane of symmetry and as a consequence he deduced only 31 out of the 32 possible crystal classes. The rhombohedral and hexagonal scalenohedral classes were included by Bravais since they may be obtained by adding a center of symmetry to two other classes of the hexagonal system, but the tetragonal bisphenoidal class, which was the one omitted by Bravais, has no center of symmetry.

Although the tetragonal bisphenoidal class was included by Hessel[19] and by Gadolin[20] in their list of the 32 classes, P. Curie,[21] the husband of Madame Curie, was the first to give full recognition to the composite plane and axis of 4-fold symmetry, under the expression " plans de symétrie alterne."

Fedorov recognized rotatory-reflection under the term " composite

[18] *Etudes Cristallographiques*, IIme Partie, p. 229, 1866.

[19] *Krystallometrie, oder Krystallonomie und Krystallographie* (reprinted in Ostwald's *Klassiker der Exakten Wissenschaften*, Nos. 88 and 89).

[20] *Acta Societatis Scientiarum Fennicae*, vol. 9, p. 28, 1871 (reprinted in German in Ostwald's *Klassiker der Exakten Wissenschaften*, no. 75.)

[21] *Bull. Franc. Soc. Min.*, vol. 7, pp. 453–5, 1884.

symmetry" ("zusammengesetzte Symmetrie"), but, as will be seen later, there are two types of composite symmetry, rotatory-reflection and rotatory-inversion.

It is absolutely necessary to recognize rotatory-reflections as symmetry operations. If rotatory-reflections are not recognized then there should be 31 classes instead of 32. In that case the tetragonal bisphenoidal class must be included in the sphenoidal class of the monoclinic system, but there are four faces in the general form of the first mentioned class and only two in the latter. In order to account for all the faces it is necessary to include rotatory-reflections. If rotatory-reflections are used in this class, it is necessary to use them in other classes also. As will be shown later, it is necessary to use rotatory-reflections in 11 classes in order that all the faces of the general form may be derived from the initial (hkl) face.

Rotatory-inversion with respect to a Center and an Axis of Rotation. Besides rotations, reflections, inversions, and rotatory-reflections there is still another type of symmetry operation effective in crystal symmetry. If we consider, for example, the dihexagonal bipyramidal class, there are 24 faces in the general form. Twenty-two out of 24 of the faces may be derived from the initial face $(hk\bar{i}l)$ by rotations, reflections, and rotatory-reflections (including with these identity). There remain two faces $(k\bar{i}h\bar{l})$ and $(\bar{i}hk\bar{l})$ which are unaccounted for. The simplest method of deriving these two faces from the $(hk\bar{i}l)$ face is by combining rotations of 60° and 300° respectively around an axis with inversion about the center of the crystal. The combined effect of rotation and inversion is considered to be a single operation, called for convenience *rotatory-inversion.* It might be well to use the term *rotoversion* for this operation. The two possible cases in crystals may be designated by the symbols $ca_{60°}$ (Fig. 15) and $ca_{300°}$ (Fig. 16).

For angles of rotation of 90° and 270° rotatory-inversions are equivalent to rotatory-reflections, and in these cases the latter term is preferred. A rotatory-inversion of 180° is equivalent to a reflection in a plane of symmetry.

The idea of rotatory-inversion was recognized by Möbius[22] as early as 1851, but has been overlooked or disregarded by most crystallographers. The following writers, however, have made use of rota-

[22] *Ber. der Konigl. Sachs. Gesell. der Wissen.*, 1851, p. 349.

tory-inversions: Gadolin,[23] Becke,[24] Liebisch,[25] Hilton,[26] Evans,[27] Saurel,[28] Tertsch,[29] Wyckoff,[30] Sen,[31] and Evans and Davies.[32]

Evans[33] uses the term " inverse axis of symmetry " for an axis of rotatory-inversion.

Hilton[34] has placed especial emphasis upon rotatory-inversions. Hilton states: " . . . it is absolutely essential for crystal structure purposes to take the rotation and rotatory-inversion " as fundamental operations, but on analysis, all that this means is that, by discarding axes of rotatory-reflection and using axes of rotatory-inversion, one obtains a satisfactory division of the 32 crystal classes into seven systems. The trigonal bipyramidal (No. 21) and ditrigonal bipyramidal (No. 22) classes then have a 6-fold principal axis and are included in the hexagonal system, while the five crystal classes with a 3-fold principal axis are placed in the rhombohedral system.

According to Hilton, both the rhombohedral (No. 17) and scalenohedral (No. 20) classes have a 3-fold rotatory-inversion axis. But it should be emphasized that in the case of both n-fold rotatory-inversion axes and n-fold rotatory-reflection axes n must be an even number. This will be brought out later in the paper. The principal axis in the rhombohedral and scalenohedral classes is a 6-fold axis of rotatory-reflection; therefore Hilton's mnemonic distinction between the hexagonal and rhombohedral system (or subsystems if one prefers six systems) fails.

Without exception the authors who use rotatory-inversions discard rotatory-reflections. The method of deriving every face of the general form from the initial face independently of the other faces proves that *both rotatory-reflections and rotatory-inversions are symmetry operations*. One is as fundamental as the other.

[23] Loc. cit., pp. 15–19.

[24] *Zeit. f. Kryst. u. Min.*, vol. 25, pp. 73–78, 1896.

[25] *Grundriss der Physikalischen Krystallographie*, pp. 66–68, Leipzig, 1896.

[26] *Mineral. Mag.*, vol. 14, pp. 261–3, 1907.

[27] *Mineral. Mag.*, vol. 15, pp. 398–400, 1912.

[28] *Zeit. f. Kryst. u. Min.*, vol. 50, pp. 1–5, 1912.

[29] *Centralblatt f. Min., Geol., u. Pal.*, 1916, pp. 171–180.

[30] *Am. Jour. Sci.* [5th series] vol. 6, pp. 288–290, 1923.

[31] *Pan-American Geologist*, vol. 42, pp. 331–4, 1924.

[32] *Elementary Crystallography*, pp. 122–131, London, 1924.

[33] *Nature*, vol. 113, p. 81, 1924.

[34] *Mineral. Mag.*, vol. 19, pp. 319–322, 1922.

The other possible composite symmetry operation, reflection-inversion, is equivalent to a simple rotation of 180°, which has already been considered.

Identical Operation. As the initial face is restored to its original position by n rotations of $360°/n$ about an n-fold axis of rotation, rotatory-reflection, or rotatory-inversion, and by two reflections (in the same plane) or two inversions, every crystal is considered to have the *identical operation.* This device is for the sake of mathematical completeness. For an n-fold axis there are n operations, provided the identical operation is used. A crystal in which only the identical operation is effective has no symmetry.

The symbol of the identical operation is 1.

The symmetry operations possible in crystals, then, are as follows:

Identical operation, 1.

Rotations, $a_{60°}$, $a_{90°}$, $a_{120°}$, $a_{180°}$, $a_{240°}$, $a_{270°}$, $a_{300°}$.

Reflection, p.

Inversion, c.

Rotatory-reflections, $ap_{60°}$, $ap_{90°}$, $ap_{270°}$, $ap_{300°}$.

Rotatory-inversions, $ca_{60°}$, $ca_{300°}$.

These operations are illustrated by Figs. 2–16 of page 165.

Rotations are usually called "operations of the first sort" and the other operations, "operations of the second sort," but too much emphasis has been placed upon this distinction.

The above tabulation suggests a new definition of symmetry operation. *Symmetry operations may be defined as movements by means of which each and every face of the general form of a crystal may be derived directly from an arbitrarily selected face.*

Symmetry Elements.

The symmetry operations take place about an axis, plane, center, or about two of these simultaneously. These are collectively called elements of symmetry, a term first used by Bravais.[35]

What are the possible elements of symmetry? Since the symmetry operations have been determined, this is an easy question to answer.

A consideration of symmetry operations shows that some of them may be obtained by repeating another operation a certain number of times. For example, $a_{180°}$ is obtained by repeating $a_{90°}$, and $a_{270°}$ by

[35] Loc. cit., p. lx.

repeating $a_{90°}$ twice. These are called *powers of operations.* $a_{180°}$ is the second power of $a_{90°}$ $[(a_{90°})^2 = a_{180°}]$ and $a_{270°}$ the third power $[(a_{90°})^3 = a_{90°}]$. The axis of 4-fold symmetry (A_4) implies the four following operations: 1, $a_{90°}$, $a_{180°}$, $a_{270°}$. In a similar manner A_2, a 2-fold axis of symmetry, implies 1 and $a_{180°}$; A_3, a 3-fold axis, implies 1, $a_{120°}$, and $a_{240°}$; and A_6, a 6-fold axis, implies 1, $a_{60°}$, $a_{120°}$, $a_{180°}$, $a_{240°}$, and $a_{300°}$.

The second powers of a reflection and inversion are each equivalent to the identical operation.

If we repeat the rotatory-reflection $ap_{90°}$ we obtain the following: 1, $ap_{90°}$, $a_{180°}$, $ap_{270°}$. These four operations are included or implied in the use of the 4-fold axis of rotatory-reflection, for which a convenient symbol is AP_4. Similarly, a 6-fold axis of rotatory-reflection (AP_6) includes the following operations which are the six powers of $ap_{60°}$: 1, $ap_{60°}$, $a_{120°}$, c, $a_{240°}$, $ap_{300°}$.

The 6-fold axis of rotatory-inversion (CA_6) includes the following operations which are the six powers of $ca_{60°}$: 1, $ca_{60°}$, $a_{120°}$, p, $a_{240°}$, $ca_{300°}$. The axis of rotatory-inversion is exactly analogous to the axis of rotatory-reflection. The third power of the former is a reflection, while the third power of the latter is inversion. The even powers in each case are ordinary rotations.

A 4-fold axis of rotatory-inversion is the equivalent of a 4-fold axis of rotatory-reflection.

The following tabulation shows the relation between the symmetry elements[36] and symmetry operations:

A_2 : 1, $a_{180°}$.

A_3 : 1, $a_{120°}$, $a_{240°}$.

A_4 : 1, $a_{90°}$, $a_{180°}$, $a_{270°}$.

A_6 : 1, $a_{60°}$, $a_{120°}$, $a_{180°}$, $a_{240°}$, $a_{300°}$.

P : 1, p.

C : 1, c.

AP_4 : 1, $ap_{90°}$, $a_{180°}$, $ap_{270°}$.

AP_6 : 1, $ap_{60°}$, $a_{120°}$, c, $a_{240°}$, $ap_{300°}$.

CA_6 : 1, $ca_{60°}$, $a_{120°}$, p, $a_{240°}$, $ca_{300°}$.

---

[36] The symbols used for the symmetry elements, with the exception of CA_6, were given in the writer's *Introduction to the Study of Minerals*, 1st ed., New York, 1912.

It will be noted that for an n-fold axis there are n operations involved; also that for an n-fold axis the angle of rotation is always $360°/n$. For the axes $\mathcal{A}P_n$ and CA_n, n is always even.

The above tabulation shows that the elements of symmetry of a crystal express in a condensed form the symmetry operations. Symmetry may be expressed either by symmetry elements or symmetry operations. As the elements of symmetry may be indicated in a more abbreviated form they are usually to be preferred.

It should be noted that $\mathcal{A}P_4$ includes A_2, and $\mathcal{A}P_6$ includes A_3 and C, and also that CA_6 includes A_3 and P. While these relations are obvious, it has been thought best to include (C) and (P) in parentheses as indicated.

The elements of symmetry occur in different positions on different crystals. A plane of symmetry (P) may have as many as 13 different positions on various crystals. An axis of 2-fold symmetry (A_2) may also occur in 13 different positions. An axis of 3-fold symmetry (A_3) and composite axis-plane of 6-fold symmetry ($\mathcal{A}P_6$) each may have five different positions. An axis of 4-fold symmetry (A_4) and composite axis-plane of 4-fold symmetry ($\mathcal{A}P_4$) each may have three different positions. For an axis of 6-fold symmetry (A_6) and composite axis-center of 6-fold symmetry (CA_6) there is only one position possible.

The positions of the various symmetry elements are best shown by means of stereographic projections (see Figs. 17–48).

Upon analysis it is found that there are in all 64 different symmetry operations involved. All of these are represented by faces of the general form of the minerals beryl (dihexagonal bipyramidal class) and garnet (hexoctahedral class). There are 24 faces on the former and 48 on the latter, but 8 faces or operations are common to the two, which gives us 64. ($24 + 48 - 8 = 64$). The eight operations common to these two are the operations of the rhombic bipyramidal (No. 8) class.

The accompanying table (p. 173–4) shows the symmetry operations corresponding to the various faces of the general form for all possible crystals. These are listed in two groups, one with four indices for hexagonal crystals, the other with three indices for non-hexagonal crystals.

These 64 operations occur combined on crystals in various ways.

Only certain operations are compatible and can occur together. It has been found that there are 31 possible combinations of the various symmetry operations or elements. These 31 together with crystals devoid of symmetry (class 1) constitute the 32 crystal classes.

OPERATIONS CORRESPONDING TO FACES OF THE GENERAL FORM.

Systems Other than Hexagonal.

Upper Faces.

1st octant	2nd octant	3rd octant	4th octant
(hkl) 1	$(\bar{h}kl)$ p'''	$(\bar{h}\bar{k}l)$ $a'_{180°}$	$(h\bar{k}l)$ p''
(hlk) p^{VI}	$(\bar{h}lk)$ $a'''_{180°}$	$(\bar{h}\bar{l}k)$ $ap''_{90°}$	$(h\bar{l}k)$ $a''_{90°}$
(khl) p^{IV}	$(\bar{k}hl)$ $a'_{90°}$	$(\bar{k}\bar{h}l)$ p^{V}	$(k\bar{h}l)$ $a'_{270°}$
(klh) $a'_{240°}$	$(\bar{k}lh)$ $ap'''_{60°}$	$(\bar{k}\bar{l}h)$ $a^{\mathrm{IV}}_{120°}$	$(k\bar{l}h)$ $ap''_{300°}$
(lhk) $a'_{120°}$	$(\bar{l}hk)$ $ap^{\mathrm{IV}}_{60°}$	$(\bar{l}\bar{h}k)$ $a''_{240°}$	$(l\bar{h}k)$ $ap'''_{300°}$
(lkh) p^{VII}	$(\bar{l}kh)$ $a'''_{90°}$	$(\bar{l}\bar{k}h)$ $ap'''_{270°}$	$(l\bar{k}h)$ $a'''_{180°}$

Lower Faces.

5th octant	6th octant	7th octant	8th octant
$(hk\bar{l})$ p'	$(\bar{h}k\bar{l})$ $a'''_{180°}$	$(\bar{h}\bar{k}\bar{l})$ c	$(h\bar{k}\bar{l})$ $a''_{180°}$
$(hl\bar{k})$ $a''_{270°}$	$(\bar{h}l\bar{k})$ $ap''_{270°}$	$(\bar{h}\bar{l}\bar{k})$ $a^{\mathrm{VII}}_{180°}$	$(h\bar{l}\bar{k})$ p^{VIII}
$(kh\bar{l})$ $a^{\mathrm{IV}}_{180°}$	$(\bar{k}h\bar{l})$ $ap'_{90°}$	$(\bar{k}\bar{h}\bar{l})$ $a^{\mathrm{V}}_{180°}$	$(k\bar{h}\bar{l})$ $ap'_{270°}$
$(kl\bar{h})$ $ap^{\mathrm{IV}}_{300°}$	$(\bar{k}l\bar{h})$ $a''_{120°}$	$(\bar{k}\bar{l}\bar{h})$ $ap'_{60°}$	$(k\bar{l}\bar{h})$ $a'''_{240°}$
$(lh\bar{k})$ $ap''_{60°}$	$(\bar{l}h\bar{k})$ $a^{\mathrm{IV}}_{120°}$	$(\bar{l}\bar{h}\bar{k})$ $ap'_{300°}$	$(l\bar{h}\bar{k})$ $a^{\mathrm{IV}}_{240°}$
$(lk\bar{h})$ $a'''_{90°}$	$(\bar{l}k\bar{h})$ p^{IX}	$(\bar{l}\bar{k}\bar{h})$ $a^{\mathrm{VI}}_{180°}$	$(l\bar{k}\bar{h})$ $ap'''_{90°}$

(Continued on next page)

Hexagonal System.

(Four Axes of Reference.)

Upper Faces.

$(hk\bar{i}l)$ 1	$(kh\bar{i}l)$ p^{V}	$(\bar{k}i\bar{h}l)$ $a'_{60°}$	$(\bar{h}i\bar{k}l)$ p'''	$(\bar{i}hkl)$ $a'_{120°}$	$(\bar{i}khl)$ p^{VI}
$(\bar{h}\bar{k}il)$ $a'_{180°}$	$(\bar{k}\bar{h}il)$ p^{IV}	$(k\bar{i}hl)$ $a'_{240°}$	$(h\bar{i}kl)$ p^{VII}	$(i\bar{h}\bar{k}l)$ $a'_{300°}$	$(i\bar{k}\bar{h}l)$ p''

Lower Faces.

$(hk\bar{i}\bar{l})$ p'	$(kh\bar{i}\bar{l})$ $a^{\mathrm{V}}_{180°}$	$(\bar{k}i\bar{h}\bar{l})$ $ap'_{60°}$	$(\bar{h}i\bar{k}\bar{l})$ $a'''_{180°}$	$(\bar{i}hk\bar{l})$ $ca'_{300°}$	$(\bar{i}kh\bar{l})$ $a^{\mathrm{VI}}_{180°}$
$(\bar{h}\bar{k}i\bar{l})$ c	$(\bar{k}\bar{h}i\bar{l})$ $a^{\mathrm{IV}}_{180°}$	$(k\bar{i}h\bar{l})$ $ca'_{60°}$	$(h\bar{i}k\bar{l})$ $a^{\mathrm{VII}}_{180°}$	$(i\bar{h}\bar{k}\bar{l})$ $ap'_{300°}$	$(i\bar{k}\bar{h}l)$ $a''_{180°}$

While there is one gap in the 32 classes to be filled, it should be remarked that all the possible symmetry operations and symmetry elements are represented by faces of the general form of the minerals beryl (dihexagonal bipyramidal class) and garnet (hexoctahedral class).

Application of the Theory of Groups to Crystal Symmetry.

Symmetry operations may be conveniently studied by means of the *theory of groups*. The group concept pervades the whole realm of mathematics, but as far as the writer knows, group theory has had no application outside the field of mathematics except in this one instance.

The theory of groups applies to a closed system of operations which have definite laws of combination. *A series of operations is said to form a group, provided the product of any two of them is equivalent to another operation of the series, and provided the inverse of any operation is also a member of the series.* Here " product " means the result of one operation followed by another. The identical operation is a member of every group since the product of any operation by its inverse gives identity. Since the above conditions are fulfilled, the symmetry operations of any crystal form a group. Let us take as an example the prismatic class of the monoclinic system with the sym-

metry elements: $A_2 \cdot P \cdot C$. Analyzing this we have the four operations: $\{1, a_{180°}, p, c\}$. The "product" of any two of these operations is another operation of the series. ($a_{180°} \cdot p = c$; $a_{180°} \cdot c = p$; $p \cdot c = a_{180°}$).

If the operations of any group are written down in a horizontal row and in a vertical column, their products may be shown in what is called a multiplication table. The "multiplication table" of the group $A_2 \cdot P \cdot C$ is as follows:

1	$a_{180°}$	p	c
$a_{180°}$	1	c	p
p	c	1	$a_{180°}$
c	p	$a_{180°}$	1

Each operation appears once in each row and once in each column. In this particular case the product of any two operations is *permutable*; that is, the result is the same regardless of the order ($a_{180°} \cdot p = p \cdot a_{180°} = c$).

This, however, is not always the case. For example, for the group $A_3 \cdot 3P$ the "multiplication table" is as follows:

1	$a'_{120°}$	$a'_{240°}$	p''	p'''	p^{IV}
$a'_{120°}$	$a'_{240°}$	1	p^{IV}	p''	p'''
$a'_{240°}$	1	$a'_{120°}$	p'''	p^{IV}	p''
p''	p'''	p^{IV}	1	$a'_{120°}$	$a'_{240°}$
p'''	p^{IV}	p''	$a'_{240°}$	1	$a'_{120°}$
p^{IV}	p''	p'''	$a'_{120°}$	$a'_{240°}$	1

Here $a'_{120°} \cdot p'' = p^{\text{IV}}$, but $p'' \cdot a'_{120°} = p'''$. These operations are not permutable.

It is also possible to construct " multiplication tables " for the other groups of crystallography.

Each of the 32 crystal classes constitutes a group. There are as many operations in a group as there are faces in the general form, and the number of operations in a group defines the *order of the group.* In geometrical crystallography there is one group of order 1, three of order 2, one of order 3 (the only prime group), five of order 4, five of order 6, five of order 8, six of order 12, one of order 16, four of order 24, and one of order 48.

Since a finite number of operations is involved, these groups are called *finite groups*; in crystal structure theory we encounter translations, screw-axes, and glide-planes, which, combined with the operations of the finite groups, constitute infinite groups of movements.

The finite groups of geometrical crystallography are also known as *point groups,* since the operations concerned all leave one point (the center of the figure) unmoved.

A group which consists entirely of the various powers of an operation is called a *cyclic group.* In this case each group may be represented by a single symmetry element. There are nine cyclic groups possible in crystallography (Classes Nos. 2, 3, 4, 9, 10, 16, 17, 21, and 23). They are represented by the tabulation on page 171. Of these only the first four are listed as cyclic by Schoenflies,[37] who apparently does not recognize cyclic groups of " the second sort."

The theory of groups has been applied to the study of crystal symmetry by Minnigerode,[38] Schoenflies,[39] Hilton,[40] Bouasse,[41] and Jaeger[42] with valuable results, but the method used by the present writer differs from the one employed by these writers, in that the symmetry operation necessary to obtain each face of a general form from the initial face is used. Schoenflies, Hilton, and all others who have employed group theory in crystallography make use of " generating "

[37] *Krystallsysteme und Krystallstructur*, Leipzig, 1891.

[38] *Neues Jahrb. f. Min. Geol. u. Pal.*, Beil. Bd. V, pp. 143–166, 1887.

[39] Loc. cit.

[40] *Mathematical Crystallography*, Oxford, 1903.

[41] *Cours de Physique*, 6 me. partie (Étude des Symétries), Paris, 1909.

[42] *Lectures on the Principle of Symmetry*, 1st ed., Amsterdam, 1917.

operations. Part of the operations of the non-cyclic groups are obtained by multiplying some of the operations of the group by an independent operation. These operations are used to "generate" the group. To illustrate, let us take the rhombic bipyramidal class or group. This group is represented by Schoenflies as follows (my symbols are used):

$$\left\{\begin{matrix} 1, & a'_{180^\circ}, & a''_{180^\circ}, & a'''_{180^\circ} \\ p', & p' \cdot a'_{180^\circ}, & p' \cdot a''_{180^\circ}, & p' \cdot a'''_{180^\circ} \end{matrix}\right\}$$

There are many different ways of representing this group. Instead of p' we might use either p'', p''', or c as one of the generating operations. The eight operations of the group are included in such an expression as the above, but they are not all expressed in terms of the operations performed on the initial face.

The preferable method is to express all eight operations independently of each other thus:

$$\{1,\ a'_{180^\circ},\ a''_{180^\circ},\ a'''_{180^\circ},\ p',\ p'',\ p''',\ c\}$$

This method brings out its relation to other groups which is not true of the method of generating operations. The use of generating operations usually conceals some of the symmetry relations of crystals. In stating the symmetry of a crystal class, it seems not unreasonable to include all the symmetry elements and not simply a part of them.

It is self-evident that a group of order n may be represented by n distinct symbols which uniquely define it. It is not necessary nor always advisable to express some of the operations as products of the others. For convenience, rotatory-reflections and rotatory-inversions are indicated in this paper by the compound symbols ap_{x° and ca_{x° respectively. Each of these symbols stands for a single operation; they do not express products of operation (expressed as products the operations would be $a_{x^\circ} \cdot p$ and $c \cdot a_{x^\circ}$ respectively). They do not necessarily represent products of operations of the group of which they are members. As an illustration, let us consider class 17, a cyclic group with the symmetry $\mathcal{AP}_6$. In this class reflection (p) is not an operation of the group; so that $a_{60^\circ} \cdot p$ expressed as a product cannot possibly represent an operation of the group. However, ap_{60° expressed as a single operation is an operation of the group.

Similarly in class 21, a cyclic group with the symmetry $C\!A_6$, inversion (c) is not an operation of group; so that $c \cdot a_{60°}$ expressed as a product cannot possibly represent an operation of this group. But $ca_{60°}$ expressed as a single operation is an operation of the group.

Another difference between the expression $a_{x°} \cdot p$ and $ap_{x°}$ is this: in the former case the order of the two operations is indicated; the latter case represents a single operation of passing from one face to another without any other specifications.

The definition of a group states; "A series of operations is said to form a group . . . etc." Now it would seem necessary to enumerate the n operations of the group before anything further is said about the group, but, by the method of generating operations used exclusively for groups of "the second sort" by Schoenflies and Hilton, some operations are expressed as products. The fact that the product of two operations of the group is another operation of the group is the essence of group theory, but this property need not be anticipated in stating the group.

Although the method of generating operations may be useful at times in crystallography, the point is brought out here that the method of deriving every face of the general form from the initial face by a distinct operation enables us to decide just what are the true elements of symmetry.

Symmetry Elements and Operations in the Various Crystal Classes.

In the following pages the operations of each crystal class or group are represented by distinct symbols (the symmetry operations of p. 170 with appropriate marks to designate the position of the symmetry element as shown in the diagrams), and the Miller symbol of the particular face which is the result of performing a given operation is indicated.

The names used for the various crystal classes are the names of the general form in each case, except that in the class without any symmetry the name asymmetric is preferred to pediad (or pedial), a name derived from the general form pedion.

The order of arrangement of the crystal classes is the same as that of Groth's *Physikalische Krystallographie*, 4th ed., pp. 335–337, Leipzig, 1905, except that the trigonal bipyramidal class is placed

after the hexagonal (or ditrigonal) scalenohedral class. Groth's numbers 19, 20, and 21 become respectively my numbers 21, 19 and 20. This change has been made so that the trigonal pyramidal, rhombohedral, trigonal trapezohedral, ditrigonal pyramidal, and hexagonal scalenohedral classes (Nos. 16–20 inclusive), which constitute the rhombohedral subsystem (or system), may be together. The trigonal bipyramidal and ditrigonal bipyramidal classes belong in the hexagonal subsystem (or system) and not in the rhombohedral or trigonal subsystem (or system).

TRICLINIC SYSTEM

1. Asymmetric (or Pediad) Class (No symmetry).

1 operation: 1 (identity)
(hkl)

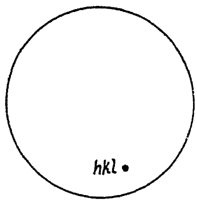


Fig. 17. Stereographic Projection of the General Form of Class 1.

2. Pinakoidal Class, C.

2 operations: 1 , c
(hkl) $(\bar{h}\bar{k}\bar{l})$

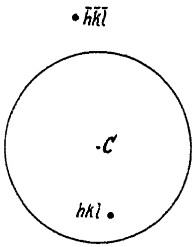


Fig. 18. Class 2.

MONOCLINIC SYSTEM

3. Sphenoidal Class, A_2.

2 operations: $\underset{(hkl)}{1}$, $\underset{(\bar{h}k\bar{l})}{a_{180°}}$.

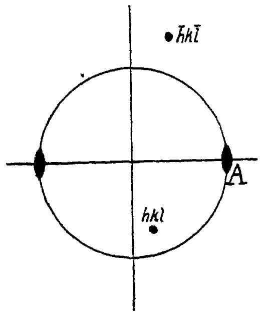


Fig. 19. Class 3.

4. Domatic Class, P.

2 operations: $\underset{(hkl)}{1}$, $\underset{(h\bar{k}l)}{p}$.

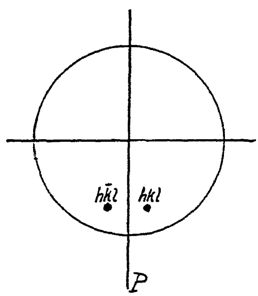


Fig. 20. Class 4.

5. Prismatic Class, $A_2 \cdot P \cdot C$.

4 operations: $\underset{(hkl)}{1}$, $\underset{(\bar{h}k\bar{l})}{a_{180°}}$, $\underset{(h\bar{k}l)}{p}$, $\underset{(\bar{h}\bar{k}\bar{l})}{c}$.

The " multiplication table " for this group is given on page 175.

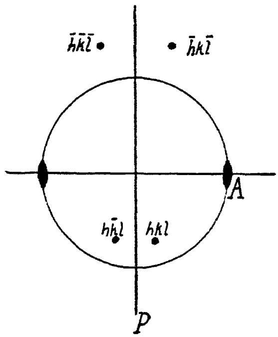


FIG. 21. Class 5.

ORTHORHOMBIC SYSTEM

6. Rhombic Bisphenoidal Class, $3A_2$.

$$\begin{array}{lcccc} \text{4 operations:} & 1\ , & a'_{180°}\ , & a''_{180°}\ , & a'''_{180°}\ . \\ & (hkl) & (\bar{h}\bar{k}l) & (h\bar{k}\bar{l}) & (\bar{h}k\bar{l}) \end{array}$$

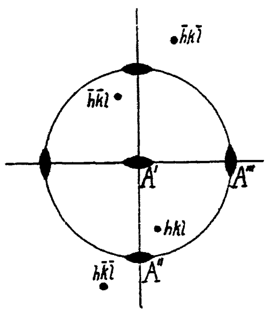


FIG. 22. Class 6.

7. Rhombic Pyramidal Class, $A_2 \cdot 2P$.

$$\begin{array}{lcccc} \text{4 operations:} & 1\ , & a'_{180°}\ , & p''\ , & p'''. \\ & (hkl) & (\bar{h}\bar{k}l) & (h\bar{k}l) & (\bar{h}kl) \end{array}$$

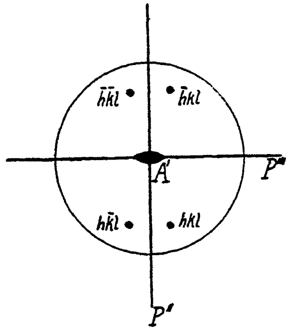


FIG. 23. Class 7.

8. RHOMBIC BIPYRAMIDAL CLASS, $3A_2 \cdot 3P \cdot C$.

8 operations: 1, $a'_{180°}$, $a''_{180°}$, $a'''_{180°}$; p', p'', p''', c.
(hkl) $(\bar{h}\bar{k}l)$ $(h\bar{k}\bar{l})$ $(\bar{h}k\bar{l})$ $(hk\bar{l})$ $(h\bar{k}l)$ $(\bar{h}kl)$ $(\bar{h}\bar{k}\bar{l})$

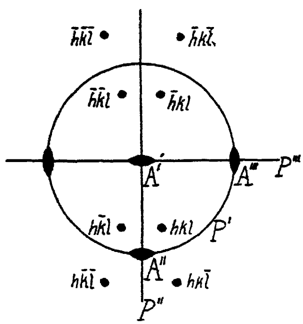


FIG. 24. Class 8.

TETRAGONAL SYSTEM.

9. TETRAGONAL BISPHENOIDAL CLASS, AP_4.

4 operations: 1, $ap'_{90°}$, $a'_{180°}$, $ap'_{270°}$.
(hkl) $(\bar{k}h\bar{l})$ $(\bar{h}\bar{k}l)$ $(k\bar{h}\bar{l})$

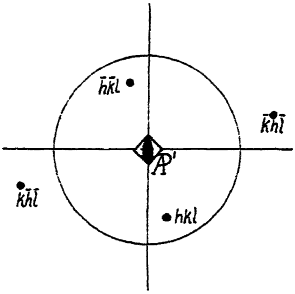


FIG. 25. Class 9.

10. TETRAGONAL PYRAMIDAL CLASS, A_4.

4 operations:	1 ,	$a'_{90°}$,	$a'_{180°}$,	$a'_{270°}$.
	(hkl)	$(\bar{k}hl)$	$(\bar{h}\bar{k}l)$	$(k\bar{h}l)$

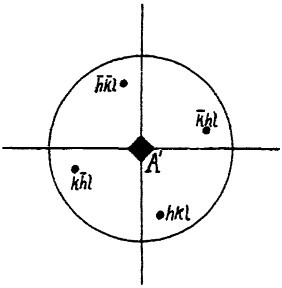
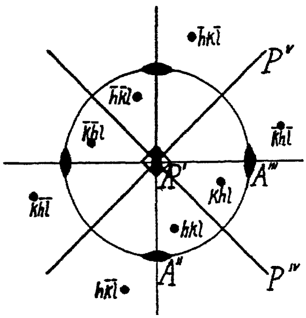


FIG. 26. Class 10.

11. TETRAGONAL SCALENOHEDRAL CLASS, $AP_4 \cdot 2A_2 \cdot 2P$.

8 operations:	1 ,	$ap'_{90°}$,	$a'_{180°}$,	$ap'_{270°}$;	$a''_{180°}$,	$a'''_{180°}$;	p^{IV},	p^{V}.
	(hkl)	$(\bar{k}h\bar{l})$	$(\bar{h}\bar{k}l)$	$(k\bar{h}\bar{l})$	$(h\bar{k}\bar{l})$	$(\bar{h}k\bar{l})$	(khl)	$(\bar{k}\bar{h}l)$



12. TETRAGONAL TRAPEZOHEDRAL CLASS, $A_4 \cdot 4A_2$.

8 operations: 1, $a'_{90°}$, $a'_{180°}$, $a'_{270°}$; $a''_{180°}$, $a'''_{180°}$, $a^{\text{IV}}_{180°}$, $a^{\text{V}}_{180°}$.
(hkl) $(\bar{k}hl)$ $(\bar{h}\bar{k}l)$ $(k\bar{h}l)$ $(k\bar{k}\bar{l})$ $(\bar{h}k\bar{l})$ $(hk\bar{l})$ $(\bar{h}\bar{k}l)$

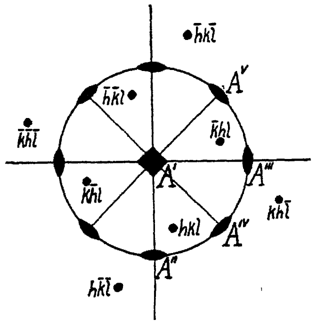


FIG. 28. Class 12.

13. TETRAGONAL BIPYRAMIDAL CLASS, $A_4[AP_4] \cdot P \cdot C$.[43]

8 operations: 1 , $a'_{90°}$, $a'_{180°}$, $a'_{270°}$, $ap'_{90°}$, $ap'_{270°}$, p' , c
(hkl) $(k\bar{h}l)$ $(\bar{h}\bar{k}l)$ $(k\bar{h}l)$ $(\bar{k}h\bar{l})$ $(k\bar{h}\bar{l})$ $(hk\bar{l})$ $(\bar{h}\bar{k}\bar{l})$

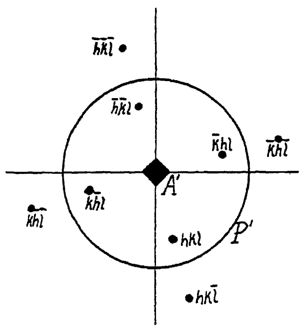


FIG. 29. Class 13.

14. DITETRAGONAL PYRAMIDAL CLASS, $A_4 \cdot 4P$.

8 operations: 1 , $a'_{90°}$, $a'_{180°}$, $a'_{270°}$; p'' , p''' , p^{IV} , p^{V}.
(hkl) $(\bar{k}hl)$ $(\bar{h}\bar{k}l)$ $(k\bar{h}l)$ $(h\bar{k}l)$ $(\bar{h}kl)$ (khl) $(\bar{k}\bar{h}l)$

[43] Since AP_4 has an operation ($a'_{180°}$) in common with A_4 it is enclosed in square brackets.

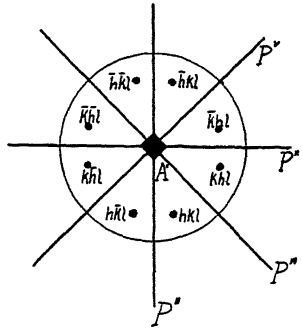


FIG. 30. Class 14.

15. DITETRAGONAL BIPYRAMIDAL CLASS, $A_4[\mathit{AP}_4] \cdot 4A_2 \cdot 5P \cdot C$.[43]

$$\begin{array}{llllllll}
\text{16 operations:} & 1\ , & a'_{90°}, & a'_{180°}, & a'_{270°}, & ap'_{90°}, & ap'_{270°}; & a''_{180°}, \\
 & (hkl) & (\bar{k}h\bar{l}) & (\bar{h}\bar{k}l) & (k\bar{h}l) & (\bar{k}h\bar{l}) & (k\bar{h}\bar{l}) & (h\bar{k}\bar{l})
\end{array}$$

$$\begin{array}{lllllllll}
a'''_{180°}, & a^{\mathrm{IV}}_{180°}, & a^{\mathrm{V}}_{180°}; & p', & p'', & p''', & p^{\mathrm{IV}}, & p^{\mathrm{V}}, & c\ . \\
(\bar{h}k\bar{l}) & (kh\bar{l}) & (\bar{k}\bar{h}\bar{l}) & (hk\bar{l}) & (h\bar{k}l) & (\bar{h}kl) & (\bar{k}hl) & (\bar{k}\bar{h}l) & (\bar{h}\bar{k}\bar{l})
\end{array}$$

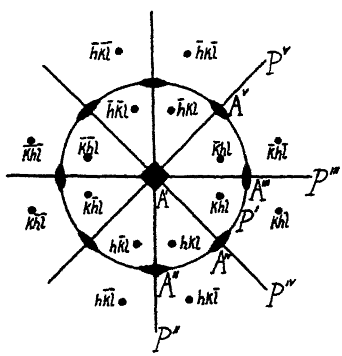


FIG. 31. Class 15.

HEXAGONAL SYSTEM.

RHOMBOHEDRAL SUBSYSTEM.

16. TRIGONAL PYRAMIDAL CLASS, A_3.

$$\begin{array}{llll}
\text{3 operations:} & 1\ , & a'_{120°}, & a'_{240°}\ . \\
 & (hk\bar{i}l) & (\bar{i}hkl) & (k\bar{i}hl)
\end{array}$$

This is the only prime group of the 32.

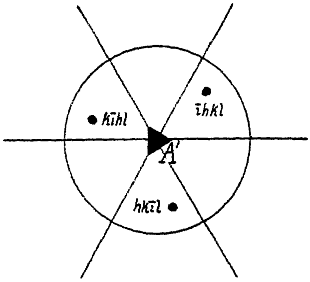


FIG. 32. Class 16.

17. RHOMBOHEDRAL CLASS, $AP_6(C)$.

6 operations:	1	$ap'_{60°}$	$a'_{120°}$	c	$a_{240°}$	$ap'_{300°}$
	$(hk\bar{i}l)$	$(\bar{k}i\bar{h}\bar{l})$	$(\bar{i}hkl)$	$(\bar{h}\bar{k}i\bar{l})$	$(k\bar{i}hl)$	$(i\bar{h}\bar{k}\bar{l})$

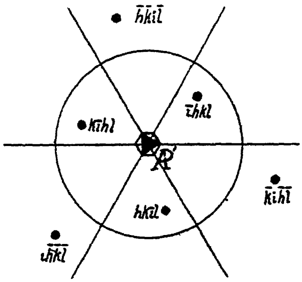


FIG. 33. Class 17.

Hilton states that the axis of symmetry in this class is a 3-fold rotatory-inversion axis, and overlooks the fact that rotatory-inversion axes are always of even period. Three powers of $ca_{120°}$ do not form a group; the six powers of $ap_{60°}$ are required. The principal axis in this class is a rotatory-reflection axis of 6-fold symmetry.

18. TRIGONAL TRAPEZOHEDRAL CLASS, $A_3 \cdot 3A_2$.

6 operations:	1	$a'_{120°}$	$a'_{240°}$	$a^{\mathrm{V}}_{180°}$	$a^{\mathrm{VI}}_{180°}$	$a^{\mathrm{VII}}_{180°}$
	$(hk\bar{i}l)$	$(\bar{i}hkl)$	$(k\bar{i}hl)$	$(kh\bar{i}\bar{l})$	$(\bar{i}kh\bar{l})$	$(h\bar{i}k\bar{l})$

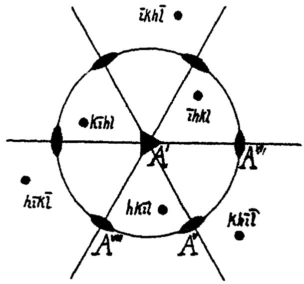


FIG. 34. Class 18.

19. DITRIGONAL PYRAMIDAL CLASS, $A_3 \cdot 3P$.

$$\begin{array}{lcccccc} \text{6 operations:} & 1\ , & a'_{120^\circ}\ , & a'_{240^\circ}\ ; & p''\ , & p'''\ , & p^{\mathrm{IV}}\ . \\ & (hk\bar{\imath}l) & (\bar{\imath}hkl) & (k\bar{\imath}hl) & (i\bar{k}\bar{h}l) & (\bar{h}i\bar{k}l) & (\bar{k}\bar{h}il) \end{array}$$

The "multiplication table" for this group is given on page 175.

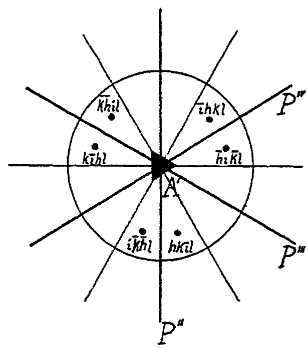


FIG. 35. Class 19.

20. HEXAGONAL SCALENOHEDRAL CLASS, $\not{A}_6 \cdot 3A_2 \cdot 3P \cdot (C)$.

$$\begin{array}{lcccccc} \text{12 operations:} & 1\ , & ap'_{60^\circ}\ , & a'_{120^\circ}\ , & c\ , & a'_{240^\circ}\ , & ap'_{300^\circ}\ ; \\ & (hk\bar{\imath}l) & (\bar{k}i\bar{h}\bar{l}) & (\bar{\imath}hkl) & (\bar{h}\bar{k}i\bar{l}) & (k\bar{\imath}hl) & (i\bar{h}\bar{k}\bar{l}) \end{array}$$

$$\begin{array}{cccccc} a^{\mathrm{V}}_{180^\circ}\ , & a^{\mathrm{VI}}_{180^\circ}\ , & a^{\mathrm{VII}}_{180^\circ}\ ; & p''\ , & p'''\ , & p^{\mathrm{IV}}\ . \\ (hk\bar{\imath}\bar{l}) & (\bar{\imath}kh\bar{l}) & (h\bar{\imath}k\bar{l}) & (i\bar{k}\bar{h}l) & (\bar{h}i\bar{k}l) & (\bar{k}\bar{h}il) \end{array}$$

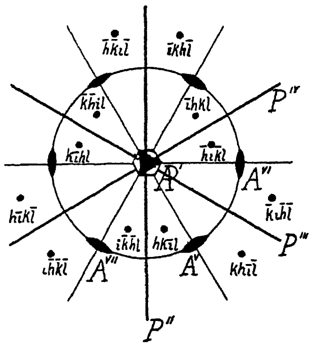


Fig. 36. Class 20.

Here again Hilton calls the principal axis a 3-fold axis of rotatory-inversion. Rotatory-inversion axes are always of even degree. The principal axis in this class is a 6-fold axis of rotatory-reflection. Unfortunately Hilton's mnemonic distinction between the hexagonal and rhombohedral subsystems fails.

HEXAGONAL SUBSYSTEM.

21. Trigonal Bipyramidal Class, $CA_6(P)$.

6 operations: 1, $ca'_{60°}$, $a'_{120°}$, p', $a'_{240°}$, $ca'_{300°}$.
$(hk\bar{i}l)$ $(k\bar{i}h\bar{l})$ $(\bar{i}hkl)$ $(hk\bar{i}\bar{l})$ $(k\bar{i}hl)$ $(\bar{i}hk\bar{l})$

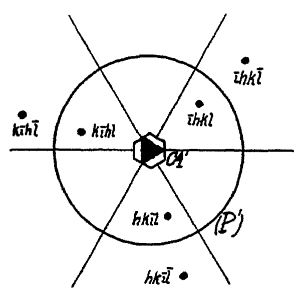


Fig. 37. Class 21.

The usual method of representing this group as $A_3 \cdot P$ is incomplete as six operations are involved instead of four.

Schoenflies and Hilton indicate the group as follows (my symbols are used):

$$\left\{\begin{matrix} 1\ , & a'_{120°}, & a'_{240°} \\ p', & p'\cdot a'_{120°}, & p'\cdot a'_{240} \end{matrix}\right\}$$

Here, two of the operations are indicated as products; p is the fourth "generating" operation. If we indicate each operation by a distinct symbol ($ca'_{60°}$ instead of $p'\cdot a'_{240°}$ and $ca'_{300°}$ instead of $p'\cdot a'_{120°}$) and not part of them as products, it is obvious that we have a cyclic group. The group $\mathcal{CA}_6$ is exactly analogous to $\mathcal{AP}_6$; in the former case reflection is the third power of ca_{60}; in the latter, inversion is the third power of $ap_{60°}$.

Jaeger[44] has stated that the trigonal bipyramidal class has a 3-fold axis of rotatory-reflection (he uses the symbol $\bar{A}_3$). But since there are six distinct operations involved, the axis is clearly 6-fold and not 3-fold. Three powers of $ap_{120°}$ do not form a group; the six powers of $ca_{60°}$ are required. $\mathcal{CA}_6$, or its equivalent, then, and not $\mathcal{AP}_3$, or its equivalent, must be used to indicate the symmetry in this class. In the general symbol of an axis of rotatory-reflection $\mathcal{AP}_n$, n is always an even number. With a series of rotatory-reflections it requires an even number of operations to come back to identity.

This class is interesting as it is the only class of the 32 for which no representative has yet been found.

22. Ditrigonal Bipyramidal Class, $\mathcal{CA}_6(P)\cdot 3A_2\cdot 3P$.

12 operations:

$$\begin{matrix} 1\ , & ca'_{60°}\ , & a'_{120°}\ , & p\ , & a'_{240°}\ , & ca'_{300°}\ ; \\ (hk\bar{i}l) & (k\bar{i}h\bar{l}) & (\bar{i}hkl) & (hk\bar{i}\bar{l}) & (k\bar{i}hl) & (\bar{i}hk\bar{l}) \\ a''_{180°}\ , & a'''_{180°}\ , & a^{\mathrm{IV}}_{180°}\ ; & p''\ , & p'''\ , & p^{\mathrm{IV}}\ . \\ (i\bar{k}\bar{h}\bar{l}) & (\bar{h}i\bar{k}\bar{l}) & (\bar{k}\bar{h}i\bar{l}) & (i\bar{k}\bar{h}l) & (\bar{h}i\bar{k}l) & (\bar{k}\bar{h}il) \end{matrix}$$

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44 Loc. cit., pp. 23–24.

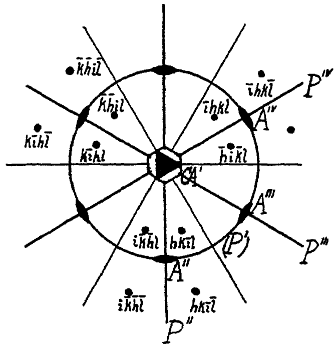

FIG. 38. Class 22.

This class is not, as Groth and others have concluded, the holosymmetric or holohedral division of a trigonal system, but belongs in the hexagonal system or subsystem. It is a subgroup (see p. 198) of class 27, but classes 17 and 20 are not subgroups of it.

23. Hexagonal Pyramidal Class, A_6.

6 operations: 1, $a'_{60°}$, $a'_{120°}$, $a'_{180°}$, $a'_{240°}$, $a'_{300°}$.
$(hk\bar{i}l)$ $(\bar{k}i\bar{h}l)$ $(\bar{i}hkl)$ $(\bar{h}\bar{k}il)$ $(k\bar{i}hl)$ $(i\bar{h}\bar{k}l)$

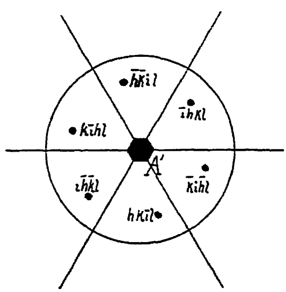

FIG. 39. Class 23.

24. Hexagonal Trapezohedral Class, $A_6 \cdot 6A_2$.

12 operations: 1, $a'_{60°}$, $a'_{120°}$, $a'_{180°}$, $a'_{240°}$, $a'_{300°}$,
$(hk\bar{i}l)$ $(\bar{k}i\bar{h}l)$ $(\bar{i}hkl)$ $(\bar{h}\bar{k}il)$ $(k\bar{i}hl)$ $(i\bar{h}\bar{k}l)$
$a''_{180°}$, $a'''_{180°}$, $a^{\text{IV}}_{180°}$, $a^{\text{V}}_{180°}$, $a^{\text{VI}}_{180°}$, $a^{\text{VII}}_{180°}$.
$(i\bar{h}\bar{k}\bar{l})$ $(\bar{h}i\bar{k}\bar{l})$ $(\bar{k}\bar{h}i\bar{l})$ $(kh\bar{i}\bar{l})$ $(\bar{i}hk\bar{l})$ $(h\bar{i}k\bar{l})$

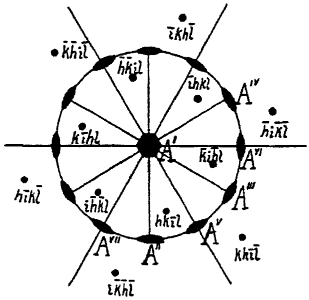

FIG. 40. Class 24.

25. HEXAGONAL BIPYRAMIDAL CLASS, $A_6\,[AP_6]\,[CA_6]\cdot(P)\cdot(C)$[45].

$$
\begin{array}{lcccccc}
\text{12 operations:} & 1\;, & a'_{60^\circ}\,, & a'_{120^\circ}\,, & a'_{180^\circ}\,, & a'_{240^\circ}\,, & a'_{300^\circ}\,; \\
 & (hk\bar{i}l) & (\bar{k}i\bar{h}l) & (\bar{i}hkl) & (\bar{h}\bar{k}il) & (k\bar{i}hl) & (i\bar{k}\bar{h}l) \\
 & ap'_{60^\circ}\,, & c\;, & ap'_{300^\circ}\,; & ca'_{60^\circ}\,, & p'\;, & ca'_{300^\circ}\,. \\
 & (\bar{k}i\bar{h}\bar{l}) & (\bar{h}\bar{k}i\bar{l}) & (i\bar{h}\bar{k}\bar{l}) & (k\bar{i}h\bar{l}) & (hk\bar{i}\bar{l}) & (\bar{i}hk\bar{l})
\end{array}
$$

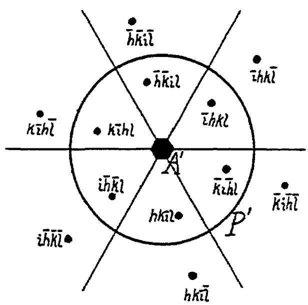

FIG. 41. Class 25.

This group is usually indicated by the equivalent of the symbol $A_6\cdot P\cdot C$, but this expression is incomplete as it includes eight operations instead of twelve. The axis of 6-fold symmetry is also an axis of rotatory-reflection and one of rotatory-inversion.

26. DIHEXAGONAL PYRAMIDAL CLASS, $A_6\cdot 6P$.

$$
\begin{array}{lllllll}
\text{12 operations:} & 1\ , & a'_{60^\circ}\ , & a'_{120^\circ}\ , & a'_{180^\circ}\ , & a'_{240^\circ}\ , & a'_{300^\circ}\ ; \\
 & (hk\bar{i}l) & (\bar{k}i\bar{h}l) & (\bar{i}hkl) & (\bar{h}\bar{k}il) & (k\bar{i}hl) & (i\bar{h}\bar{k}l) \\
 & p''\ , & p'''\ , & p^{\mathrm{IV}}\ , & p^{\mathrm{V}}\ , & p^{\mathrm{VI}}\ , & p^{\mathrm{VII}}\ . \\
 & (i\bar{k}\bar{h}l) & (\bar{h}i\bar{k}l) & (\bar{k}\bar{h}il) & (kh\bar{i}l) & (\bar{i}khl) & (h\bar{i}kl)
\end{array}
$$

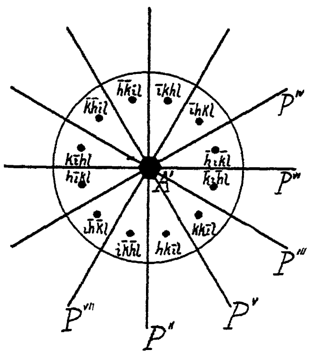

FIG. 42. Class 26.

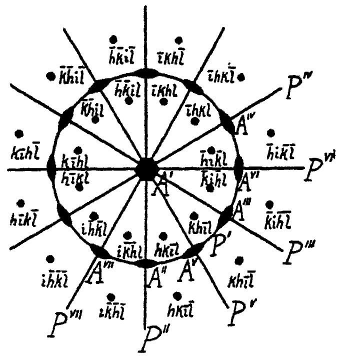

FIG. 43. Class 27.

27. DIHEXAGONAL BIPYRAMIDAL CLASS,

$$A_6\,[\mathit{AP}_6]\,[\mathit{CA}_6]\cdot 6A_2\cdot 6P\cdot(P)\cdot(C).$$ [45]

$$
\begin{array}{lllllll}
\text{24 operations:} & 1\ , & a'_{60^\circ}\ , & a'_{120^\circ}\ , & a'_{180^\circ}\ , & a'_{240^\circ}\ , & a'_{300^\circ}\ ; \\
 & (hk\bar{i}l) & (\bar{k}i\bar{h}l) & (\bar{i}hkl) & (\bar{h}\bar{k}il) & (k\bar{i}hl) & (i\bar{h}\bar{k}l)
\end{array}
$$

$$
\begin{array}{lllllll}
ap'_{60^\circ}\ , & c\ , & ap'_{300^\circ}\ ; & ca'_{60^\circ}\ , & p'\ , & ca'_{300^\circ}\ ; & a''_{180^\circ}\ , \\
(\bar{k}i\bar{h}\bar{l}) & (\bar{h}\bar{k}i\bar{l}) & (i\bar{h}\bar{k}\bar{l}) & (k\bar{i}h\bar{l}) & (hk\bar{i}\bar{l}) & (\bar{i}hk\bar{l}) & (i\bar{k}\bar{h}\bar{l}) \\
a'''_{180^\circ}\ , & a^{\mathrm{IV}}_{180^\circ}\ , & a^{\mathrm{V}}_{180^\circ}\ , & a^{\mathrm{VI}}_{180^\circ}\ , & a^{\mathrm{VII}}\ ; & p''\ , & p'''\ , \\
(\bar{h}i\bar{k}\bar{l}) & (\bar{k}\bar{h}i\bar{l}) & (kh\bar{i}\bar{l}) & (\bar{i}kh\bar{l}) & (h\bar{i}k\bar{l}) & (i\bar{k}\bar{h}l) & (\bar{h}i\bar{k}l) \\
p^{\mathrm{IV}}, & p^{\mathrm{V}}\ , & p^{\mathrm{VI}}\ , & p^{\mathrm{VII}}\ . & & & \\
(\bar{k}\bar{h}il) & (hk\bar{i}l) & (\bar{i}hkl) & (h\bar{i}kl) & & &
\end{array}
$$

[45] In groups 25 and 27, A_6, AP_6, and CA_6, each have two operations (a'_{120° and a'_{240°) in common, hence square brackets are placed around AP_6 and CA_6.

As in class 25, the principal axis is an axis of rotatory-reflection and rotatory-inversion as well as an ordinary 6-fold axis.

ISOMETRIC SYSTEM.

28. Tetartoidal Class, $4A_3 \cdot 3A_2$.

12 operations:	1,	$a'_{120°}$,	a'_{240},	$a''_{120°}$,	$a''_{240°}$;	$a'''_{120°}$,
	(hkl)	(lhk)	(klh)	$(\bar{h}l\bar{h})$	$(\bar{l}\bar{h}k)$	$(\bar{l}h\bar{k})$
	$a'''_{240°}$;	$a^{\mathrm{IV}}_{120°}$,	$a^{\mathrm{IV}}_{240°}$;	$a'_{180°}$,	$a''_{180°}$,	$a'''_{180°}$.
	$(k\bar{l}\bar{h})$	$(\bar{k}\bar{l}h)$	$(l\bar{h}\bar{k})$	$(\bar{h}\bar{k}l)$	$(h\bar{k}\bar{l})$	$(\bar{h}k\bar{l})$

This is the group of "tetrahedral rotations."

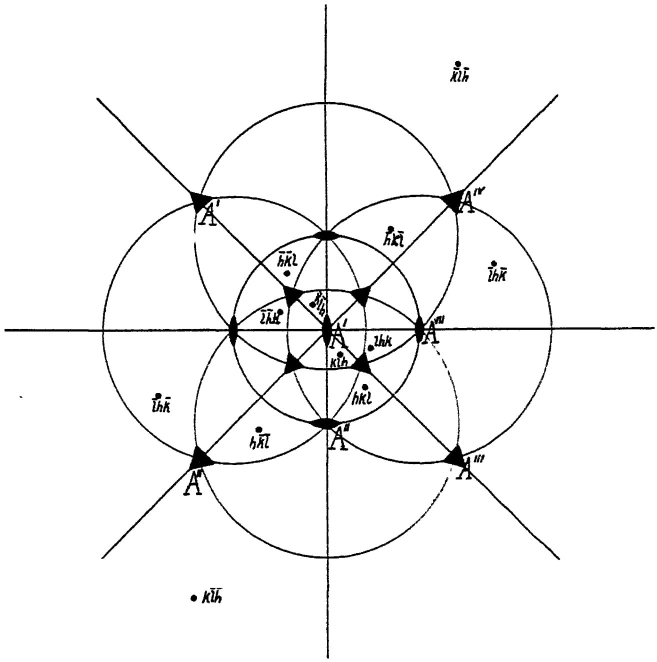

Fig. 44. Class 28.

29. Gyroidal Class, $3A_4 \cdot 4A_3 \cdot 6A_2$.

24 operations:

$$\begin{array}{cccccccc}
 & 1\,, & a'_{90°}, & a'_{180°}, & a'_{270°}; & a''_{90°}, & a''_{180°}, & a''_{270°}; \\
 & (hkl) & (\bar{k}hl) & (\bar{h}\bar{k}l) & (k\bar{h}l) & (h\bar{l}k) & (h\bar{k}\bar{l}) & (hl\bar{k}) \\
a'''_{90°}, & a'''_{180°}, & a'''_{270°}; & a'_{120°}, & a'_{240°}; & a''_{120°}, & a''_{240°}; & a'''_{180°}, \\
(lk\bar{h}) & (\bar{h}k\bar{l}) & (\bar{l}kh) & (lhk) & (klh) & (\bar{k}l\bar{h}) & (\bar{l}\bar{h}k) & (\bar{l}h\bar{k})
\end{array}$$

$$\begin{array}{ccccccccc}
a'''_{240°}; & a^{IV}_{120°}, & a^{IV}_{240°}; & a^{IV}_{180°}, & a^{V}_{180°}, & a^{VI}_{180°}, & a^{VII}_{180°}, & a^{VIII}_{180°}, & a^{IX}_{180°}. \\
(k\bar{l}\bar{h}) & (\bar{k}\bar{l}h) & (l\bar{h}\bar{k}) & (kh\bar{l}) & (\bar{k}\bar{h}\bar{l}) & (\bar{l}\bar{k}\bar{h}) & (\bar{h}\bar{l}\bar{k}) & (l\bar{k}h) & (\bar{h}lk)
\end{array}$$

This is the group of "octahedral rotations."

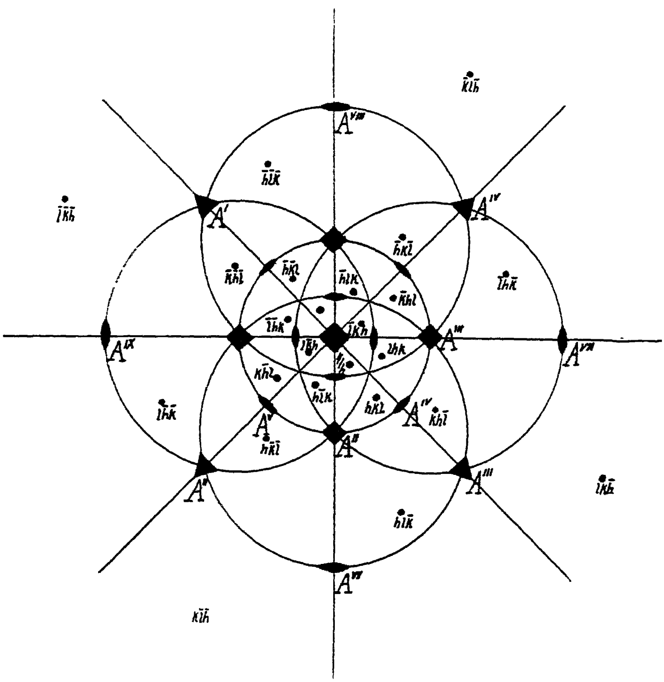

Fig. 45. Class 29.

30. DIPLOIDAL CLASS, $4\mathcal{A}\!\!P_6 \cdot 3A_2 \cdot 3P \cdot (C)$.

24 operations:	1,	$ap'_{60°}$,	$a'_{120°}$,	c,	$a'_{240°}$,	$ap'_{300°}$;	$ap''_{60°}$,	
	(hkl)	$(\bar{k}\bar{l}\bar{h})$	(lhk)	$(\bar{h}\bar{k}\bar{l})$	(klh)	$(\bar{l}\bar{h}\bar{k})$	$(lh\bar{k})$	
$a''_{120°}$,	$a''_{240°}$,	$ap''_{300°}$,	$ap'''_{60°}$,	$a'''_{120°}$,	$a'''_{240°}$,	$ap'''_{300°}$,	$ap^{\text{IV}}_{60°}$,	
$(\bar{k}l\bar{h})$	$(\bar{l}\bar{h}k)$	$(k\bar{l}h)$	$(\bar{k}lh)$	$(\bar{l}h\bar{k})$	$(k\bar{l}\bar{h})$	$(l\bar{h}k)$	$(\bar{l}hk)$	
$a^{\text{IV}}_{120°}$,	$a^{\text{IV}}_{240°}$,	$ap^{\text{IV}}_{300°}$;	$a'_{180°}$,	$a''_{180°}$,	$a'''_{180°}$;	p',	p'',	p'''.
$(\bar{k}\bar{l}h)$	$(l\bar{h}\bar{k})$	$(kl\bar{h})$	$(\bar{h}\bar{k}l)$	$(h\bar{k}\bar{l})$	$(\bar{h}k\bar{l})$	$(hk\bar{l})$	$(h\bar{k}l)$	$(\bar{h}kl)$

In this class and in class 32 there are $4ap_{60°}$, but the third power of each of these operations gives the same face $(\bar{h}\bar{k}\bar{l})$ by inversion, which is additional proof that the center of symmetry is a true element of symmetry.

This is the "extended group of tetrahedral rotations."

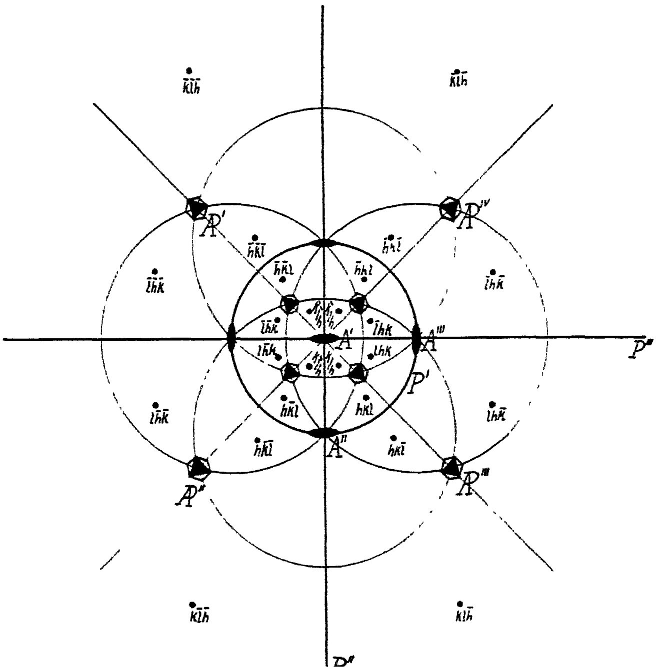

FIG. 46. Class 30.

31. Hextetrahedral Class, $3\bar{A}_4 \cdot 4A_3 \cdot 6P$.

24 operations:

1 ,	$ap'_{90°}$,	$a'_{180°}$,	$ap'_{270°}$;	$ap''_{90°}$,	$a''_{180°}$,	$ap''_{270°}$;
(hkl)	$(\bar{k}h\bar{l})$	$(\bar{h}\bar{k}l)$	$(k\bar{h}\bar{l})$	$(\bar{h}\bar{l}k)$	$(h\bar{k}\bar{l})$	$(\bar{h}l\bar{k})$

$ap_{90°}$,	$a_{180°}$,	$ap_{270°}$;	$a'_{120°}$,	$a'_{240°}$;	$a''_{120°}$,	$a''_{240°}$;	$a'''_{120°}$,
$(l\bar{k}\bar{h})$	$(\bar{h}k\bar{l})$	$(\bar{l}\bar{k}h)$	(lhk)	(klh)	$(\bar{k}l\bar{h})$	$(\bar{l}\bar{h}k)$	$(\bar{l}h\bar{k})$

$a'''_{240°}$;	$a^{IV}_{120°}$,	$a^{IV}_{240°}$;	p^{IV},	p^{V},	p^{VI},	p^{VII},	p^{VIII},	p^{IX}.
$(k\bar{l}\bar{h})$	$(\bar{k}\bar{l}h)$	$(l\bar{h}\bar{k})$	(khl)	$(\bar{k}\bar{h}l)$	(hlk)	(lkh)	$(h\bar{l}\bar{k})$	$(\bar{l}k\bar{h})$

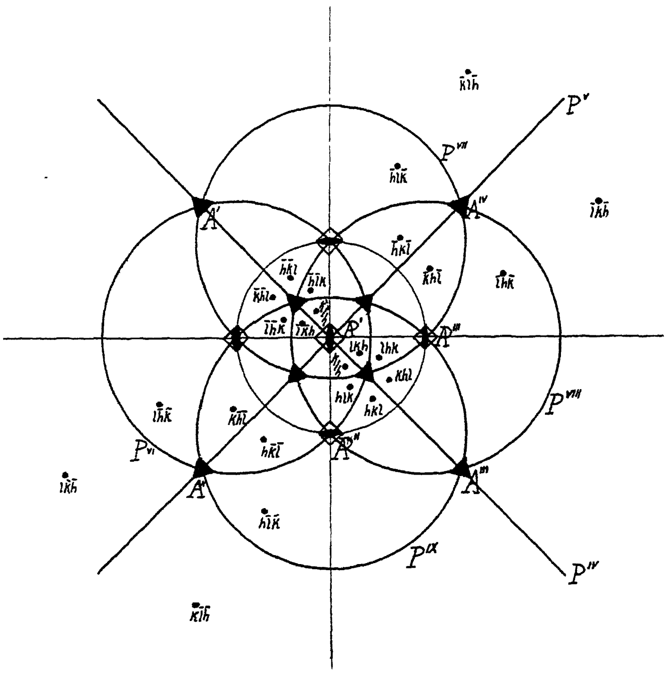

Fig. 47. Class 31.

32. Hexoctahedral Class, $3A_4[3\bar{A}_4] \cdot 4\bar{A}_6 \cdot 6A_2 \cdot 9P \cdot (C)$.[46]

[46] Since the $3\bar{A}_4$ have operations ($a_{180°}$) in common with $3A_4$, they are placed in square brackets.

48 operations:

1, (hkl)	$a'_{90°}$, $(\bar{k}hl)$	$a'_{180°}$, $(\bar{h}\bar{k}l)$	$a'_{270°}$, $(k\bar{h}l)$	$ap'_{90°}$, $(\bar{k}h\bar{l})$	$ap'_{270°}$; $(k\bar{h}\bar{l})$		
$a''_{90°}$, $(h\bar{l}k)$	$a''_{180°}$, $(h\bar{k}\bar{l})$	$a''_{270°}$, $(hl\bar{k})$	$ap''_{90°}$, $(\bar{h}\bar{l}k)$	$ap''_{270°}$, $(\bar{h}l\bar{k})$	$a'''_{90°}$, $(lk\bar{h})$	$a'''_{180°}$, $(\bar{h}k\bar{l})$	$a'''_{270°}$, $(\bar{l}kh)$
$ap'''_{90°}$, $(l\bar{k}\bar{h})$	$ap'''_{270°}$, $(\bar{l}\bar{k}h)$	$ap'_{60°}$, $(\bar{k}\bar{l}\bar{h})$	$a'_{120°}$, (lhk)	c, $(\bar{h}\bar{k}\bar{l})$	$a'_{240°}$, (klh)	ap'_{300}, $(\bar{l}\bar{h}\bar{k})$	$ap''_{60°}$, $(lh\bar{k})$
$a''_{120°}$, $(\bar{k}l\bar{h})$	$a''_{240°}$, $(\bar{l}\bar{h}k)$	$ap''_{300°}$, $(k\bar{l}h)$	$ap'''_{60°}$, $(\bar{k}lh)$	$a'''_{120°}$, $(\bar{l}h\bar{k})$	$a'''_{240°}$, $(k\bar{l}\bar{h})$	$ap'''_{300°}$, $(l\bar{h}k)$	$ap^{IV}_{60°}$, $(\bar{l}hk)$
$a^{IV}_{120°}$, $(\bar{k}\bar{l}h)$	$a^{IV}_{240°}$, $(l\bar{h}\bar{k})$	$ap^{IV}_{300°}$, $(kl\bar{h})$	$a^{IV}_{180°}$, $(kh\bar{l})$	$a^{V}_{180°}$, $(\bar{k}\bar{h}\bar{l})$	$a^{VI}_{180°}$, $(\bar{l}\bar{k}\bar{h})$	$a^{VII}_{180°}$, $(\bar{h}\bar{l}\bar{k})$	$a^{VIII}_{180°}$, $(l\bar{k}h)$
$a^{IX}_{180°}$, $(\bar{h}lk)$	p', $(hk\bar{l})$	p'', $(h\bar{k}l)$	p''', $(\bar{h}kl)$	p^{IV}, (khl)	p^{V}, $(\bar{k}\bar{h}l)$	p^{VI}, (hlk)	p^{VII}, (lkh)
p^{VIII}, $(h\bar{l}\bar{k})$	p^{IX}. $(\bar{l}k\bar{h})$						

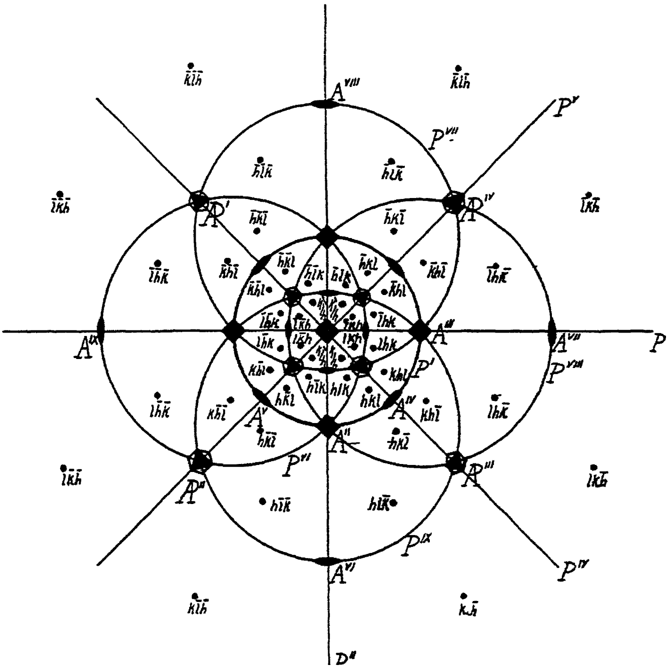

FIG. 48. Class 32.

See remark under Class 30.

This is the "extended group of octahedral rotations."

It has now been demonstrated that each face of the general form in any crystal class may be considered to be the result of some operation performed on the initial face. It is not necessary to use the product of two operations in order to derive a given face as is the usual custom. It is this fact that enables us to determine what the real symmetry operations are.

Subgroups.

If a certain portion of the operations of a group taken alone form a group, these operations constitute a *subgroup*. For example, in the group $\{1, a_{60°}, a_{120°}, a_{180°}, a_{240°}, a_{300°}\}$ 1, $a_{120°}$, and $a_{240°}$ form a subgroup; the same is also true of 1 and $a_{180°}$. The number of operations of a subgroup is always an aliquot part of the number of operations of the group itself. For convenience, both identity and the group itself are here considered to be subgroups of any group.

The subgroups of each of the 32 groups or crystal classes are shown in the table on page 200. Apparently this is the first time that a complete list of these subgroups has ever been published.

Classes 27 (dihexagonal bipyramidal) and 32 (hexoctahedral) are unique in that they are not subgroups of any other group except themselves. At the same time it should be noted that every one of the 32 classes is a subgroup of either class 27 or class 32; classes 1–8 inclusive, and 16–20 inclusive are subgroups of both of them.

With the present arrangement of the 32 classes (it is not true of Groth's arrangement) the subgroups of each group appear before the group itself, This arrangement of the 32 classes first appeared in a text-book by the author.[47] A study of the table on page 200 will show that the sequence of the classes is only in minor part an arbitrary one.

Group Theory and Crystal Systems.

Since hemihedral and tetartohedral groups are subgroups of the holohedral groups, hemihedrism seems at first glance to have some

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[47] *Introduction to the Study of Minerals and Rocks*, 2nd ed., p. 80, New York, 1921.

sanction from the standpoint of group theory.[48] It should be recognized, however, that the systems were chosen first, and so consideration should be given to all the subgroups of the various groups. It is possible to choose other groups as holohedral groups of systems which would have corresponding hemihedral groups. For example, classes 1 to 7 inclusive are subgroups of class 8. We might, then, place classes 1–8 inclusive in one system and consider classes 1–7 inclusive as hemihedral, tetartohedral, and ogdohedral divisions. This illustration serves to show that group theory of itself has no particular bearing on the validity of hemihedrism.

The question of holohedrism and hemihedrism seems to rest almost entirely upon whether or not the crystal systems are fundamental. As it must be admitted that crystal classes and not crystal systems are fundamental, the concept of holohedrism and hemihedrism loses its significance. The systems are largely a matter of convenience.

One point, however, is settled by means of group theory, and that is the separation of the hexagonal system into two divisions. The trigonal pyramidal, rhombohedral, trigonal trapezohedral, and hexagonal scalenohedral classes constitute the rhombohedral subsystem (or system). The trigonal bipyramidal and ditrigonal bipyramidal classes must be placed in the hexagonal subsystem (or system) and not in a trigonal or rhombohedral subsystem (or system) as has been done by Groth, Dana, Tutton, Moses, Moses and Parsons, Lewis, Swartz, Wülfing, Niggli, Jaeger, Cole, Spencer, Rinne, and others. Classes 16 to 19 inclusive (see table p. 200) are subgroups of class 20, but class 20 is not a subgroup of class 22.

Group theory has no bearing on the question whether classes 16 to 27 inclusive should be placed in one system or in two.

The inclusion of the five classes enumerated, and not the seven given by Groth, in a subsystem of the hexagonal system (or the rhombohedral system), is confirmed by crystal structure theory. Crystals of the five classes 16 to 20 inclusive have as a space lattice either a rhombohedron or a hexagonal prism. Crystals of the other seven classes, 21 to 27 inclusive, have only a hexagonal prism as a space lattice. The Laue diagrams of crystals of classes 21 and 22 are similar to those of classes 23 to 27 inclusive and not to those of classes 16 to 20 inclusive.

---

[48] See Hilton, *Mathematical Crystallography*, p. 92.

TABLE OF THE 32 CRYSTAL CLASSES WITH THEIR SUBGROUPS

System	No.	Name of Class	Order	Symmetry	Subgroups
Triclinic	1	Asymmetric	1	None	1.
	2	Pinakoidal	2	C	1, 2.
Monoclinic	3	Sphenoidal	2	A_2	1, 3.
	4	Domatic	2	P	1, 4.
	5	Prismatic	4	$A_2 \cdot P \cdot C$	1, 2, 3, 4, 5.
Orthorhombic	6	Rhombic bisphenoidal	4	$3A_2$	1, 3, 6.
	7	" pyramidal	4	$A_2 \cdot 2P$	1, 3, 4, 7.
	8	" bipyramidal	8	$3A_2 \cdot 3P \cdot C$	1, 2, 3, 4, 5, 6, 7, 8.
Tetragonal	9	Tetragonal bisphenoidal	4	Æ$_4$	1, 3, 9.
	10	" pyramidal	4	A_4	1, 3, 10.
	11	" scalenohedral	8	Æ$_4 \cdot 2A_2 \cdot 2P$	1, 3, 4, 6, 7, 9, 11.
	12	" trapezohedral	8	$A_4 \cdot 4A_2$	1, 3, 6, 10, 12.
	13	" bipyramidal	8	A_4[Æ$_4$]$\cdot P \cdot C$	1, 2, 3, 4, 5, 9, 10, 13.
	14	Ditetragonal pyramidal	8	$A_4 \cdot 4P$	1, 3, 4, 7, 10, 14.
	15	" bipyramidal	16	A_4[Æ$_4$]$\cdot 4A_2 \cdot 5P \cdot C$	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15.
Hexagonal — Rhombohedral Subsystem	16	Trigonal pyramidal	3	A_3	1, 16.
	17	Rhombohedral	6	Æ$_6(C)$	1, 2, 16, 17.
	18	Trigonal trapezohedral	6	$A_3 \cdot 3A_2$	1, 3, 16, 18.
	19	Ditrigonal pyramidal	6	$A_3 \cdot 3P$	1, 4, 16, 19.
	20	Hexagonal scalenohedral	12	Æ$_6 \cdot 3A_2 \cdot 3P \cdot (C)$	1, 2, 3, 4, 5, 16, 17, 18, 19, 20.
Hexagonal — Hexagonal Subsystem	21	Trigonal bipyramidal	6	$CA_6(P)$	1, 4, 16, 21.
	22	Ditrigonal bipyramidal	12	$CA_6(P) \cdot 3A_2 \cdot 3P$	1, 3, 4, 7, 16, 18, 19, 21, 22.
	23	Hexagonal pyramidal	6	A_6	1, 3, 16, 23.
	24	" trapezohedral	12	$A_6 \cdot 6A_2$	1, 3, 6, 16, 18, 23, 24.
	25	" bipyramidal	12	A_6[Æ$_6$][CA_6]$(P) \cdot (C)$	1, 2, 3, 4, 5, 16, 17, 21, 23, 25.
	26	Dihexagonal pyramidal	12	$A_6 \cdot 6P$	1, 3, 4, 7, 16, 19, 23, 26.
	27	" bipyramidal	24	A_6[Æ$_6$][CA_6]$(P) \cdot 6A_2 \cdot 6P \cdot (C)$	1, 2, 3, 4, 5, 6, 7, 8, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27.
Isometric	28	Tetartoidal	12	$4A_3 \cdot 3A_2$	1, 3, 6, 16, 28.
	29	Gyroidal	24	$3A_4 \cdot 4A_3 \cdot 6A_2$	1, 3, 6, 10 12, 16, 18, 28, 29.
	30	Diploidal	24	4Æ$_6 \cdot 3A_2 \cdot 3P \cdot (C)$	1, 2, 3, 4, 5, 6, 7, 8, 16, 17, 28, 30.
	31	Hextetrahedral	24	3Æ$_4 \cdot 4A_3 \cdot 6P$	1, 3, 4, 6, 7, 9, 11, 16, 19, 28, 31.
	32	Hexoctahedral	48	$3A_4[3$Æ$_4] \cdot 4$Æ$_6 \cdot 6A_2 \cdot 9P \cdot (C)$	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 28, 29, 30, 31, 32

Subgroups found in two or more groups are known as common subgroups. The common subgroup of the highest order is called the *greatest common subgroup.*

Two of the six systems may be defined in terms of the greatest common subgroup. In the isometric system the greatest common subgroup is group 28 with the symmetry $4A_3 \cdot 3A_2$. In the hexagonal system the greatest common subgroup is group 16 with the symmetry A_3. But for the other systems this scheme fails. Group 3 (A_2), for example, is the greatest common subgroup for both the orthorhombic and tetragonal systems. Neither the monoclinic nor the triclinic system has a common subgroup (except identity). It is evident, then, that the theory of groups is not a sufficient guide for the establishment of crystal systems, although it may be of some assistance.

Summary.

The symmetry operations of a crystal are the operations that are necessary to derive each and every face of the general form from an initial face.

The symmetry operations possible in crystals are the following:

Identical operation: 1.

Rotations about an axis: $a_{60°}$, $a_{90°}$, $a_{120°}$, $a_{180°}$, $a_{240°}$, $a_{270°}$, $a_{300°}$.

Reflection in a plane : p.

Inversion about the center: c.

Rotatory-reflections: $ap_{60°}$, $ap_{90°}$, $ap_{270°}$, $ap_{300°}$.

Rotatory-inversions: $ca_{60°}$, $ca_{300°}$.

All of these symmetry operations are represented by faces of the general form on crystals of either beryl (dihexagonal bipyramidal class) or garnet (hexoctahedral class).

Counting the various positions on a crystal, of axes, planes, rotatory-reflection axes, and rotatory-inversion axes of symmetry, there are, in all, 64 symmetry operations found on crystals.

Since inversion is a single operation, it should be used instead of a rotatory-reflection of 180°. If there is one 2-fold axis of rotatory-reflection, there must be an infinite number of such axes.

Both rotatory-inversions and rotatory-reflections must be used as symmetry operations.

The terms *rotoflection* and *rotoversion* may be used for rotatory-reflection and rotatory-inversion respectively.

The following are the elements of symmetry possible in crystals:

Axes of symmetry: A_2, A_3, A_4, A_6.

Plane of symmetry: P.

Center of symmetry: C.

Rotatory-reflection axis-plane: AP_4, AP_6.

Rotatory-inversion axis-center: CA_6.

Each of the elements of symmetry implies the existence of n symmetry operations which are powers of a single operation.

Each of the above elements of symmetry has actually been observed on crystals.

The mathematical theory of groups may be applied to the study of crystal symmetry. The symmetry operations of a crystal form a finite group. The group may be expressed by means of symmetry operations or symmetry elements. Each of the 32 crystal classes constitutes a distinct group. Each of the elements of symmetry taken by itself represents a cyclic group. Of the 32 groups nine are cyclic groups. The symmetry operations and symmetry elements of each of the 32 groups have been determined. The use of both rotatory-reflections and rotatory-inversions reconciles our usual conception of symmetry with group theory.

The trigonal bipyramidal class (No. 21) should be represented by the symmetry element CA_6 and not by $A_3 \cdot P$, for it is a cyclic group formed by the various powers of the operation $ca_{60°}$. CA_6 is also a symmetry element in the ditrigonal bipyramidal (No. 22), hexagonal bipyramidal (No. 25), and dihexagonal bipyramidal (No. 27) classes. The hexagonal bipyramidal (No. 25) and dihexagonal bipyramidal (No. 27) classes include as symmetry elements A_6, AP_6, and CA_6.

In the diploidal (No. 30) and hexoctahedral (No. 32) classes the symmetry elements include $4AP_6$; here inversion is an operation (the third power of $ap_{60°}$) common to each of these four rotatory-reflection axes. This is additional evidence that the center of symmetry is a true element of symmetry.

The tetragonal bipyramidal (No. 13), ditetragonal bipyramidal (No. 15), and hexoctahedral (No. 32) classes include as symmetry elements both A_4 and AP_4.

In the tabulation of the 32 crystal classes (p. 200), the order of Groth has been followed except that the trigonal bipyramidal (No. 21) class has been placed after the hexagonal scalenohedral (No. 20) class.

In this tabulation all the subgroups of each of the 32 groups have been determined for the first time, apparently. As now arranged, the subgroups of each group appear in the tabulation before the group itself; so that the sequence of the classes is only in minor part arbitrary. Numbers, then, as well as names may be used for the 32 crystal classes.

Although the so-called hemihedral groups are subgroups of the so-called holohedral groups, the idea of hemihedrism receives no particular sanction from the theory of groups.

Although the classes of the hexagonal and isometric systems each have a greatest common subgroup, group theory is not a sufficient guide for the establishment of the crystal systems. Group theory, however, does show that the five classes Nos. 16 to 20 inclusive and not the seven classes Nos. 16 to 22 inclusive should be included in the rhombohedral subsystem (or system in case seven systems are used).

In conclusion it may be stated that an analytical study of crystal symmetry with the aid of the theory of groups establishes definitely just what constitues the symmetry operations and symmetry elements of crystals. The subject of crystal symmetry would now seem to have reached something like finality by reason of its mathematical nature.

ACKNOWLEDGMENTS.

For my first introduction to the theory of groups I am indebted to Hilton's *Mathematical Crystallography and the Theory of Groups of Movements*, Oxford, 1903.

Discussions with my colleague, Professor William A. Manning of the Mathematics Department, have also been of much assistance to me.

MINERALOGICAL LABORATORY, STANFORD UNIVERSITY,
September, 1925.

Proceedings of the American Academy of Arts and Sciences.

Vol. 61. No. 8.—July, 1926.

STUDIES ON ETHIOPIAN BRACONIDÆ, WITH A CATALOGUE OF THE AFRICAN SPECIES.

By Charles T. Brues.

STUDIES ON ETHIOPIAN BRACONIDÆ, WITH A CATALOGUE OF THE AFRICAN SPECIES.[1]

By Charles T. Brues.

Since the publication of my recent paper on South African Braconidæ in the Annals of the South African Museum,[2] I have received several additional collections of material and these are dealt with in the present paper. They include the following series: A lot from the Durban Museum, received through the courtesy of the Director, E. C. Chubb, collected almost entirely in Natal; an extensive series belonging to the Imperial Bureau of Entomology in London, sent by Dr. G. A. K. Marshall, collected in various parts of eastern and southeastern Africa; a small, but very interesting, lot received from Dr. Joseph Bequaert, collected in the Belgian Congo, mainly by his brother, Dr. M. Bequaert.

I have been able to recognize a number of previously described species in these collections, but in spite of the large number of African forms made known during the past twenty years, a considerable series prove to be hitherto undescribed and descriptions of these are appended.

The most recent catalogue of Braconidæ is that contained in the Genera Insectorum issued in 1904. This contains 161 African species, but since that time about one thousand additional ones have been described from this region. As these descriptions are widely scattered, it has seemed advisable to prepare a new catalogue and this has been done at considerable labor, with the hope that it may aid in any further studies of the African fauna, which is extremely extensive and very imperfectly known, especially among the smaller species.

The types of the new species received from the Durban Museum and the Imperial Bureau of Entomology have been returned to these institutions.

The small family Alysiidæ has been included in the present account as it is sometimes considered to rank as a subfamily of Braconidæ.

Subfamily STEPHANISCINÆ.

Doryctophasmus Enderlein.

Arch. Naturg., Jahrg. 78A, Heft 2, p. 18 (1912).

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[1] Contribution from the Entomological Laboratory of the Bussey Institution, Harvard University, No. 260.

[2] Vol. 19, pp. 1–150, 1924.

Doryctophasmus africanus sp. nov.

♀. Length 5.5 mm.; ovipositor 4 mm. Generally dull brownish yellow; antennæ and sheaths of ovipositor blackish; propodeum, first tergite and tip of abdomen piceous; pleuræ darkened above; wings subhyaline, veins dark brown; stigma black, pale yellowish at base and tip. Head, seen from above, fully as thick as wide, the temples parallel behind the eyes, then suddenly contracted; occiput broadly and very deeply emarginate; eyes strongly protuberant; ocelli in a large triangle, the posterior pair nearly twice as far from one another as from the eye-margin; anterior ocellus placed just below a sharp transverse ridge which defines the upper edge of a large frontal excavation. Front and vertex shagreened, semiopaque; face finely and transversely wrinkled; malar space one-fourth the length of the eye, cheeks smooth, temples faintly shagreened. Antennæ very slender; scape scarcely longer than thick; first flagellar joint longer than the scape and pedicel together, much widened and flattened, except at apex, and very closely punctate (these punctures are evidently sense-pits); following joints very slender and much elongated. Pronotum well-developed, shagreened, with a striated furrow along its posterior margin; middle lobe of mesonotum prominent, as broad as long, with a broad and deep median impression; notauli weakly crenulate, meeting in a broad curve before the base of the scutellum; mesonotum densely shagreened; axillæ very large, triangular. Scutellum small, with four foveæ at the base. Propodeum about as long as wide at base, narrowed apically, evenly convex; base shagreened; apex reticulate. Pro- and mesopleuræ above opaque, the latter below shining; sides of propodeum subshining, shagreened. Hind coxæ broadly oval, shagreened, much swollen but not toothed below. Abdomen subpetiolate; first tergite noticeably widened near apex which is twice as wide as the base, very finely rugose, with longitudinal wrinkles at apex; second tergite longitudinally aciculate, as broad as long, with a raised line near each side, outside which the surface is finely granulate; apical segments smooth and polished. Legs short and stout. Radial cell nearly attaining the wing-tip; second section of radius shorter than the first, the two together as long as the width of the stigma; third very long and straight. Second cubital cell very short above, three times longer below, the first intercubitus continuous with the recurrent nervure and very oblique; the second intercubitus vertical, half as long as the first and longer than the second section of the radius; first section of cubitus strongly sinuous; basal vein thickened; submedian straight, the nervellus interstitial with it; nervulus post-

furcal by its own length. Submediellan cell in hind wing one-fourth as long as the mediellan; basellan vein prolonged downwards nearly to the wing margin; radiellan cell simple, narrow.

Type from Mfongosi, Zululand (W. E. Jones), March.

This species seems to be most closely related to Doryctophasmus although it may quite possibly not be congeneric with the type species which is from New Guinea.

SUBFAMILY BRACONINAE.

Microbracon Ashmead.

Bull. Colorado Biol. Assoc., vol. 1, p. 15 (1890).

Microbracon suspectus sp. nov.

♀. Length 4 mm.; ovipositor two-thirds as long as the abdomen. Head and base of abdomen yellowish; thorax mostly black above and below. Wings distinctly infuscated; stigma and veins black or piceous. Legs black, the second joint of trochanters, four anterior tarsi and calcaria fulvous. Antennæ black. Head rather pale yellow, with the ocellar area and a large triangular spot on the occiput, black. Thorax with the notauli, scutellum and a broad band including practically all the pleuræ, ferruginous. Abdomen pale brownish yellow except the tip of the petiole and the median half of the third and following abdominal segments which are black. Body rather noticeably white pubescent, especially on the sides of the propodeum and on the tibiæ. Head less than half wider than long, smooth on the vertex and behind; sharply and obliquely narrowed behind; the front and face finely shagreened and subopaque. Malar space shorter than the antennal scape, Antennæ with more than 22 joints (tips missing), slender and much tapered apically, first four flagellar joints nearly twice as long as broad, gradually shortening but all joints considerably longer than wide. Ocelli rather large, on a distinct tubercle, the posterior pair half as far from one another as from the eye. Mesonotum and scutellum faintly sparsely punctulate, shining. Notauli narrow, clearly defined, the middle lobe not noticeably elevated. Propodeum shining, finely sparsely rugose on the sides; medially with a quite distinctly defined impression; on its posterior face obliquely striate on each side of the groove, the striæ converging posteriorly. Pro- and mesopleuræ shining, the latter faintly shagreened below; sides of propodeum minutely rugoso-punctate, opaque. Petiole of abdomen scarcely widened behind, its median plate triangular, flat,

irregularly sculptured. Gaster elongate oval, slightly more than twice as long as broad. Second segment less than twice as wide as long, its hind margin strongly sinuate at the middle; median basal area distinctly defined by a fine marginal raised line, elongate triangular, extending halfway across the segment; disc of segment without trace of impressions. Third segment three-fourths as long as the second on the median line, separated from it by a deep, broad, coarsely crenulated furrow; anterior angles greatly produced forward and indistinctly separated from the rest of the segment by an impression; the posterior edge with a very distinct rim. Fourth, fifth and sixth segments progressively shorter, each with a delicate but very distinct raised posterior rim. Entire gaster finely rugose and subopaque, the sculpture growing finer and the surface less opaque apically. Legs quite slender although the hind femora are moderately and the hind tibiæ slightly thickened. Stigma distinctly more than twice as long as broad; first section of radius one-third as long as the second, third equal to the other two; second cubital cell very long and slightly narrowed apically; second intercubitus nearly perpendicular to the second section of the radius and slightly over one-third its length; first discoidal cell distinctly petiolate, the base nearly twice as high as the apex; recurrent nervure received more than half its length before the tip of the first cubital cell.

Type from Umbilo, Durban, Natal, June 21, 1915 (A. L. Bevis). Type in the Durban Museum.

This species will run to *M. sectator* in my key to the South African species (Ann. South African Mus., vol. 19, p. 19, 1924) but it differs by the strongly sinuate suturiform articulation, the vertical second intercubitus, slender legs and distinct median impression on the propodeum. The anterior corners of the third segment are quite distinctly separated from the disk which indicates an approach to Chelonogastra although the species could not otherwise be confused with that genus.

Microbracon hector sp. nov.

Length 5–5.5 mm.; ovipositor as long as the abdomen, exclusive of the petiole. Head, thorax and legs mostly black; abdomen fulvous, blackened medially on the fourth and following segments; wings very distinctly and evenly infuscated; veins and stigma piceous. The head is fulvous except the mouthparts and upper surface; the thorax is marked with fulvous as follows: propleuræ; tegulæ; notauli, broadened laterally in front and confluent behind; an oblique stripe on

propodeum behind the spiracle. Second joint of all trochanters yellow; legs otherwise black except for fuscous calcaria. The black markings of the apical abdominal segments do not extend to the sides and the ovipositor sheaths are black. Head decidedly less than twice as broad as long, the temples gradually narrowed and broadly rounded behind; ocelli close together, the posterior ones less than one-third as far from one another as from the eye; front, vertex, temples and cheeks smooth and polished; face very finely rugose. Antennæ with 29 joints, short, their tips reaching about to the apex of the third abdominal segment; joints gradually growing shorter, basal ones slightly longer than wide, others quadrate. Mesonotum smooth and shining, broader than long, the notauli deeply impressed, the median lobe very slightly protuberant. Scutellum subtriangular, as long as broad, smooth and shining, its basal impression narrow, but very sharply and clearly foveate. Propodeum smooth and shining, without median carina or groove. Pleura impunctate, shining; mesopleura without groove. Abdomen rather elongate, the gaster more than twice as long as wide; apex of second segment not quite twice the median length; suturiform line straight except for its curve forwards at the side, very finely crenulate; base of second segment entirely without median basal area and the disk without indications of grooves. Third segment two-thirds as long as the second, more than four times as wide as long; fourth to sixth gradually shorter; the second and third segments are finely rugose and subshining, the third without distinct apical rim; fourth more shining and less clearly rugose; fifth and sixth progressively more nearly smooth; ovipositor sheaths with short pubescence. Legs unusually stout, hind femora, tibiæ and tarsi distinctly flattened. Stigma more than twice as long as wide; first section of radius one-third as long as the second; third slightly shorter than the two together; second cubital cell not narrowed apically, the second intercubitus perpendicular to and scarcely half as long as the second section of the radius; first discoidal cell scarcely petiolate, its tip almost as wide as its base; recurrent nervure entering the first cubital cell distinctly before its tip. Body, especially the legs, conspicuously white pubescent.

Type from Durban, Natal, November 10, 1919 (C. N. Barker). Type in the Durban Museum.

In my key to the South African species (Ann. South African Mus., vol. 19, p. 18, 1924) this will run to couplet 10. From *M. sesamiæ* Cameron it differs by its entirely black legs, infuscated wings and elongate abdomen. From *M. celer* Szép. as I have identified that

species it differs in the same way; *M. celer* also possesses a distinct median basal area on the second segment.

Microbracon recessus Szépligeti.

Ann. Mus. Nat. Hungarici, vol. 11, p. 598 (1911) (*Bracon*).

A considerable series (15 specimens) of both sexes from Morogoro, Tanganyika (A. H. Ritchie) sent by the Imperial Bureau of Entomology appear to be this species as they agree with Szépligeti's description in all details which he mentions. The face is elevated medially as an elongate tubercle which is very conspicuous in both sexes. The eyes are rather small, entire, twice as wide as the length of the sharply grooved malar space. The head is faintly shagreened above, the mesonotum distinctly so and the abdominal sculpture shows a distinct tendency to form longitudinal aciculations, especially in the male.

The series was bred from *Sylepta derogata,* the Cotton Leaf-roller. In India *Microbracon lefroyi* Dudgeon & Gough has been reared from caterpillars of this pest, but that species may be distinguished from the present one by the fewer antennal joints, partly black body and in lacking a large distinct oval area at each side of the second abdominal segment which extends halfway to the posterior margin.

Also from Durban, Natal, 1 ♀ (A. L. Bevis) sent by the Durban Museum; and Weenen, Natal (H. P. Thomasset), two females sent by the Imperial Bureau of Entomology.

Microbracon postfurcalis Brues.

Ann. South African Mus., vol. 19, p. 28 (1924).

Doonside, Natal, January 13, 1917 (A. L. Bevis). The nervulus is not quite so clearly postfurcal as in the type.

Microbracon latifasciatus Brues.

Ann. South African Mus., vol. 19, p. 22 (1924).

Umbilo, Durban, Natal, August 4, 1923 (A. L. Bevis).

Microbracon hieroglyphicus Brues.

Ann. South African Mus., vol. 19, p. 123 (1924).

Umbilo, Durban, Natal, October 12, 1919 (A. L. Bevis); Durban, Natal, September 27, 1919.

Microbracon celer Szépligeti.

Bull. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 101 (1913) (*Bracon*).

There is a specimen probably of this species from Umbilo, Durban, Natal, September 6, 1919 (A. L. Bevis). There is a distinct raised smooth median basal area on the second segment which is fully four times as broad as long; the second cubital cell is one-half as high at apex as long above, the first discoidal cell twice as high at base as at apex and the third section is as long as the other two while the first is half as long as the second. The antennæ are 26-jointed.

Braconella Szépligeti.

Ann. Mus. Nat. Hungarici, vol. 4, p. 587 (1906).
ROMAN, Entom. Tidskr., vol. 31, p. 115 (1910).
BRUES, Ann. S. African Mus., vol. 19, p. 19 (1924).

Numerous specimens are before me, belonging to two very distinct forms. One series of both sexes from Doonside and Durban, Natal have the thorax shagreened and subopaque and these are what I regarded as *B. minor* (1924). The others have the head above, mesonotum and the pleuræ polished and sparsely, minutely punctate. The female of this form measures 4 mm. and the males are smaller. Possibly they are referable to *B. major* Szép. which Roman (1910) thinks is not separable on the basis of size and color as described by Szépligeti. The shining species is from Zanzibar and Durban.

Iphiaulax Förster.

Verh. naturf. Ver. preuss. Rheinlande, vol. 19, p. 243 (1862).

This genus, or group of genera, includes over 300 described African species and as it is well represented throughout the world, especially in the tropics, presents a very difficult taxonomic problem. Good structural characters are available for a large majority of the species and a great range of color characters of both body and highly ornamented wings are exhibited in almost endless permutation. Many generic names have been proposed to include one, several, or occasionally a larger group of species. Of these already at least sixteen are represented in the African fauna and many more are based on Malayan and Neotropical species in addition to a few others from other regions. This immense complex has been generally known as Iphiaulax, but this is not the oldest name to be applied to any of the species now

generally included. They were first included in the old genus Bracon from which all have necessarily been removed as this name is based upon a totally different species of another group (*Cremnops* Förster, non Fabricius). Cyanopterus Haliday (1836) antedates Iphiaulax by many years and has recently been used to include some species in addition to the type.

If Cyanopterus and Iphiaulax be finally recognized as distinct genera, both names will remain in use and I feel satisfied that it will be possible in the future to recognize a number of genera, but cannot believe that any attempt to do so at present does more than to add greater confusion to that now existant.

I have, therefore, referred to all the African species as Iphiaulax *sens lat.* in the present paper as well as in the catalogue. There is also another reason for this procedure; several entomologists, particularly Szépligeti, have applied the same specific name to different species in the several genera or groups. Any final attempt to combine any of these genera must entail the proposal of new names for such homonyms and the introduction of any new names on a tentative basis would be most unfortunate. Consequently it will be noticed that several specific names appear more than once in the list.

These insects are evidently in a very active state of evolution and as is usual in such cases there has been the tendency on the part of a number of workers to multiply generic names, quite generally without reference to one another. It is sincerely to be hoped that no more may be added until the status of those already used has been determined.

Iphiaulax bucephalus sp. nov.

♀. Length 11 mm.; ovipositor 5 mm. Fulvous, the abdomen black beyond the petiole, except the median area of the second segment; antennæ and the hind tibiæ and tarsi black. Wings variegated; basal section to the middle of the median cell pale yellow; remainder black, small spot in first cubital cell above yellow, a small streak below this spot and a spot below the apex of the first cubital cell hyaline; a spot beyond the second intercubitus and a minute spot above it also hyaline; basal half of stigma yellow; apical half black. Head nearly as thick as wide; temples semicircularly narrowed; occiput excavated medially; front impressed, less deeply so in the middle than at the sides above each antenna; head shining, smooth above and behind, the face sparsely punctate at the sides and with a few transverse striæ in the center. Eyes oval, more than twice as broad as

the malar space which bears an indistinct furrow. Antennæ slender, longer than the body, the apex of the scape excavated externally at tip which is prolonged below; first flagellar joint one half longer than wide, joints beyond the middle strongly transverse. Thorax long and slender, notauli impressed for their entire length, but broad and very shallow; median lobe very slightly elevated. Entire thorax smooth and shining; scutellum with a very narrow, finely crenulate groove at base. First segment of abdomen about half longer than wide, but little narrowed basally; median lobe smooth, not very convex; depressed side pieces of equal width, with some very indistinct cross carinæ and a carinate external margin. Second and following segments smooth and shining. Second segment a little wider than its length at the middle, the apical margin strongly curved; basal area small, very distinct, prolonged as a carina that extends nearly to the suture and then reappears on the depressed basal third of the third segment; at each side of the median carina there extends from the basal area a very short, oblique carina that crosses a very distinct broad groove which extends along the sides of the area and back along each side of the median carina; sides each with a large oval impression bounded inwardly by a ridge that extends from the anterior angle backwards and toward the median line; first suture very deeply impressed, but not crenulate. Third segment as long as the second at the sides, but much shorter medially, its oblique grooves strongly crenulate, meeting at the median line and attaining the sides be' ind the middle so that the anterior corners are very large and triangular. Suture at base of fourth segment sharply crenulate; the anterior corners of the fourth segment large, the oblique grooves strongly crenulate. Apical margins of all segments curved and declivous, but not margined; gaster broadly lanceolate, broadest at the apex of the third segment. Legs slender, the posterior tibiæ and sheaths of ovipositor rather densely clothed with stiff hairs. Radius arising considerably before the middle of the stigma, extending almost to the wing-tip; nervulus slightly postfurcal; cubitus sharply bent at base; stalk at base of second cubital cell one-fourth as long as the recurrent nervure; upper side of second cubital cell two and one-half times as long as the apical side.

Type from Natal; Illivo River, April 6, 1916.

This species will run to *I. trichiosomus* Cameron in my key to the South African species, but differs conspicuously in the sculpture of the abdomen. It falls in the group Ipobracon. It resembles *I. atricauda* Enderlein in color and sculpture, but the cubitus is angulate at the

base, the basal suture of the third abdominal segment is crenulate and the basal median area of the third segment much smaller.

The form of the suturiform articulation is unusual as the posterior margin of the second segment projects backward over the base of the third and does not appear to be anchylosed with it except at the sides.

Iphiaulax bipunctipennis sp. nov.

♀. Length 9 mm.; ovipositor 12 mm. Fulvous, the head somewhat paler; antennæ and sheaths of ovipositor black; last joint of four hind tarsi piceous; wings pale yellowish, each fore wing with a hyaline streak below the base of the stigma and a pair of small round blackish spots along the costal margin, one between the basal vein and stigma and the other at the apex of the stigma; veins and stigma fulvous except the tip of the stigma which is included in the apical wing spot. Head about as thick as wide, the temples very broad behind the eyes, then suddenly contracted; occiput weakly excavated; surface smooth and polished except the face which is shining and sparsely punctate with a small impunctate space at the middle. Eyes broadly oval, three times as wide as the malar space. Scape elongate oval, simple at apex; basal joints of flagellum longer than wide, those beyond quadrate but not becoming transverse. Thorax rather elongate, smooth except for sparse minute punctures on the sides of the propodeum. Notauli not impressed; scutellum at base with a rather coarsely crenate groove. First segment of abdomen fully half longer than wide, but little narrowed basally; its median part only slightly convex, irregularly, more or less longitudinally striate reticulate; side pieces narrow, of even width, longitudinally grooved. Second segment not much wider than long, smooth on the large anterior corners, rather coarsely longitudinally striated elsewhere; median area small, shield-shaped, not very clearly defined, more finely sculptured than the rest of the segment; the anterior corners are set off by a short oblique groove inwardly and behind by an oval, impressed nearly smooth lateral area. First suture broad, evenly striate. Third and fourth segments finely reticulate striate, their posterior margin smooth and polished. Third segment as long as the second, its anterior corners raised, smooth inwardly, not limited behind by a distinct furrow. Base of fourth segment with a striate groove. Radial vein originating near the middle of the stigma and ending a considerable distance before the wing tip, its third section one-third longer than the second; cubitus straight or scarcely bent at the base; nervulus

interstitial or faintly postfurcal; recurrent nervure entering the first cubital cell very near its tip.

Type from the Belgian Congo, Lubumbashi, Katanga, lat. 11° 45′ S., long. 27° 40′ E., November 15, 1920 (Mich. Bequaert). Paratype from the same locality, December; this is considerably smaller, 7.5 mm.

This species will be easily recognized by the peculiar color pattern of the wing. It does not fit very well in any of the groups defined by Szépligeti but will run to Ipobracon in his table.

Iphiaulax fulvoater sp. nov.

♀. Length 15 mm.; ovipositor 9 mm. Head, thorax and four anterior legs entirely dull fulvous; antennæ, abdomen and hind legs, including coxæ, black. Anterior wing pale yellow on basal sixth, black beyond, except for the stigma which is orange on basal two-thirds with a streak below it, a spot beyond the upper end of the recurrent nervure and a very thin streak along the second inter-cubitus hyaline. Hind wing entirely black, except the extreme base.

Head as thick as broad, the temples full, very sharply rounded behind; occiput strongly emarginate at the middle; front very deeply excavated above each antenna. Face rugose, coarsely transversely striate in the middle. Eyes elongate oval, not emarginate inwardly, nearly three times as long as the malar space. Antennal scape much enlarged apically, one-half longer than wide, compressed, the apex produced below and deeply emarginate apically; first joint of flagellum fully twice as long as thick; second and third much shorter; following becoming strongly transverse, those near apex quadrate. Third joint of maxillary palpi noticeably enlarged. Pronotum with a crenulate transverse groove. Mesonotum elongate, notauli indicated in front, absent behind; propleura with a curved impression medially; meso-pleura with a smaller one anteriorly above. First segment of abdomen nearly twice as long as broad, very strongly elevated medially for its entire length; reticulate striate, the sculpture coarser and strongly oblique laterally; side furrows narrow, foveately cross-ridged apically. Second segment strongly widened behind, apex one-fourth broader than long, the posterior margin raised, arcuate. Median area strongly elevated, convex, especially in front, nearly half as wide and half as long as the segment, triangular and continued to the margin by a sharp median carina, its surface shagreened basally, beyond finely longitudinally and irregularly striate. Lateral areas minute, smooth, triangular; from them there extends behind an oblique ridge which

separates a deep inner and more shallow outer depression; inner impressions with several longitudinal carinæ; sides coarsely irregularly striate. Third segment coarsely and irregularly striate, anterior corners rather large, smooth, triangular; wider and shorter than the second; its basal groove striate medially, coarsely foveate laterally, oblique grooves broad and more or less smooth; apex smooth, without marginal line, not elevated. Fourth segment shorter than the third, similarly sculptured; fifth more finely striate over entire surface; sixth smooth. Sheaths of ovipositor clothed with short hairs. Radial cell reaching the tip of wing; radius arising before middle of stigma, its first section half as long as the first intercubitus; cubitus angulate near the base; stalk of second cubital cell one-third as long as the recurrent nervure; second cubital cell slightly widened apically; nervulus slightly but distinctly postfurcal.

Type from Rhodesia; Bulawayo.

This species resembles *I.* (*Eumorpha*) *nigripennis* Szép. in color but the fourth and fifth segments are striate and the hind legs are entirely black.

Iphiaulax radiator sp. nov.

♀. Length 7 mm.; ovipositor as long as the abdomen. Head and thorax, including coxæ and trochanters, black; palpi, narrow orbits, tegulæ, basal scutellar furrow metanotum and spot on propodeum behind reddish or yellowish; abdomen dull yellow, infuscated beyond the second segment; legs clear light yellow, apex of hind tibiæ and hind tarsi black. Fore wing from base to the basal vein yellowish hyaline, moderately infuscated beyond, with a hyaline cloud occupying the first cubital cell, another oval one about the second intercubitus and a small indistinct one at the base of the radial cell; hind wing yellowish hyaline, weakly infuscated on apical third; stigma black, venation pale basally, dark on the apical half of the wing. A stout species with broadly oval abdomen, more or less the shape of Microbracon. Head decidedly broader than thick, gradually narrowed behind the eyes, the occiput broadly and gently excavated; front very weakly impressed above the antennæ. Antennæ not quite as long as the body 47-jointed; scape strongly compressed, simple at apex, more or less subtriangular, but little longer than high at tip; three basal joints of flagellum longer than wide; those beyond quadrate. Face shining, very sparsely punctulate; malar space one-fourth the width of the eye, with a rugulose spot just median to a very indistinct furrow. Mesonotum short, broadly elevated medially, the

notauli obsolete; scutellar groove distinctly crenulate. Propodeum evenly convex above. First segment of abdomen as broad as long, the sides distinctly angulate at the basal third; basal half smooth, gently concave, including the median portion which is convex behind where it is coarsely longitudinally striate-reticulate; side pieces broad, imperfectly cross-striated; lateral edge raised, carinate. Median basal area of second segment large, triangular, smooth, about half as long as the segment; radiating from this are about 12 short carinæ, the median one attaining the margin of the segment and the lateral ones attaining a broad lateral groove which extends from near the anterior corner backwards and inwards to near the posterior margin; sides of this segment coarsely punctate-reticulate; posterior margin curved on each side and feebly bent forwards toward the middle, more than twice as long as the median length. Third, fourth and fifth segments coarsely longitudinally, more or less irregularly striate, their posterior borders forming a smooth, weakly convex rim. Third segment four times as broad as long; basal groove broad, coarsely striate; anterior corners rather small, convex. Fourth and fifth segments successively shorter, each with a crenate basal groove. Legs short, the hind pair rather stout. Radial cell rather long, but not reaching the wing tip; cubitus with a very slight angulate bend at its extreme base; nervulus interstitial; recurrent nervure entering the first cubital cell very near the apex; second cubital cell with parallel sides; first intercubitus strongly oblique; the second nearly perpendicular, almost half as long as the second section of the radius.

Type from Natal; Durban, February (C. N. Barker).

This species is related to *I. spilopus* Cameron, to which it will run in my key to the South African species. It differs by the shorter radial cell in which the third section of the radius is hardly as long as the second, by the wholly black (not annulate) hind tarsi, large triangular plate on second abdominal segment and by the presence of pale spots on the apical half of the wing.

Iphiaulax phosphor Brues.

Ann. South African Mus., vol. 19, p. 42 (1924).

Seven specimens, including the female which has not been described. Natal; Durban, December to April (♂ ♀) (C. N. Barker) Widenham, December (A. L. Bevis).

The female as usual differs by its smaller eyes, three times as long as the malar space; the median areas of the third and fourth segments

are practically smooth although there is a trace of several weak striæ on the third; the yellow at the base of the wing is less extensive and extends over only the basal two-thirds of the submedian cell; the hyaline crossband below the stigma does not extend completely across the wing, disappearing at the middle of the discoidal cell. The nervulus varies from almost interstitial to strongly postfurcal.

A complete description of the female is given below:

♀. Length 15 mm.; ovipositor 5 mm. Head, thorax and first abdominal segment dull fulvous, antennæ and remainder of abdomen black; legs fulvous, hind tibiæ and tarsi black. Wings yellow halfway to the nervulus, black beyond; stigma yellow, black at tip; a small yellow spot below the stigma, a hyaline streak across the first cubital cell, enlarged below the cubitus; a small spot on the second intercubitus and a spot above this in the radial cell; hind wing yellow on basal fourth. Head wider than thick, obliquely rounded and narrowed behind the eyes; occiput broadly and deeply excavated; impressed line behind ocelli much deepened at the sides; frontal impression large. Face finely rugose, transversely wrinkled at the middle and punctate below at the sides. Eye nearly circular, feebly emarginate inwardly; malar furrow rather distinct, half as long as the width of the eye. Face clothed with conspicuous, sparse, long, black bristly hairs. Antennal scape one-half longer than broad, compressed, dentate below at tip and very deeply excised apically on the outer side; first flagellar joint one-half longer than wide, following rapidly growing shorter, only half as long as broad in the middle of the flagellum, quadrate apically. Palpi slender, third joint of maxillary ones slightly swollen. Thorax elongate, notauli distinct except near the scutellum; basal groove of scutellum very delicately crenulate. First segment of abdomen no longer than broad; median lobe broad, pyriform; shagreened, shining at tip; side furrows deep, broad and smooth. Second segment, as well as the following ones, smooth and shining; slightly broader than long, the posterior margin arcuate; basal area small, scarcely elevated, followed by a carina that broadens behind into an indistinct triangular tubercle; carina bordered by a linear groove on each side; sides of segment with large shallow impressions, broadened behind. Third segment more than twice as broad as long, its basal suture not crenulated although the oblique ones separating the large corners are broadly crenulate; the basal depressed portion with a short strong median carina. Fourth and fifth segments smooth, convex, with moderately large corners; their basal

and oblique furrows narrow, but strongly crenulated; following segments rapidly narrowed to the quite acute apex; hypopygium large, prominent, acute. The abdomen is elongate-oval, broadest at the tip of the second segment and quite pointed at the apex; the third and fourth segments are moderately convex apically and without any apical impressed line. Radial cell reaching the wing-tip, cubitus very strongly bent at the base; nervulus interstitial or very clearly postfurcal by about one-third of its own length, recurrent nervure entering the first cubital cell very near its tip; second cubital cell slightly widened apically, the outer side one-half as long as the upper. Submediellan cell of hind wing minute, triangular; transverse discoidal nervure entirely absent.

It is rather difficult to be satisfied with a generic location for this species as the nervulus is sometimes very strongly postfurcal. The abdomen does not have the form characteristic of Archibracon particularly on account of the crenulated furrows and I think it had best remain in Iphiaulax although it seems very probable that the two genera will have to be merged.

Iphiaulax kolleri Cameron.

Ann. Soc. Ent. Belgique, vol. 56, p. 366 (1912).

A female from Walikale in the northeastern Belgian Congo, January, collected by Dr. Jos. Bequaert. The type was from Dima, Belgian Congo.

Iphiaulax decorus Cameron.

Ann. South African Mus., vol. 5, p. 50 (1906).
BRUES, ibid., vol. 19, p. 62 (1924).

One male. Natal; Krantzloof, May (C. N. Barker).

Iphiaulax dodsi Cameron.

Ann. South African Mus., vol. 5, p. 51 (1906).
BRUES, ibid., vol. 19, p. 63 (1924).

One male. Natal; Upper Tongat, November (C. N. Barker).

Iphiaulax bellona Brues.

Ann. South African Mus., vol. 19, p. 52 (1924).

One female. Rhodesia; Bulawayo, August (E. C. Chubb).

Iphiaulax trimeni Cameron.

Rec. Albany Mus. Grahamstown, vol. 1, p. 240 (1905).
CAMERON, Ann. South African Mus., vol. 5, p. 41 (1906) (*xanthopterus*).
BRUES, ibid., vol. 19, p. 64 (1924) (*xanthopterus*).

Rhodesia: Bulawayo, August (E. C. Chubb), one female.

Iphiaulax neger Szépligeti.

Termes. Füzetek, vol. 24, p. 365 (1901).
SZÉPLIGETI, Ergebn. deutsch. Zent. Afrika Exped. 1907–08, vol. 3, p. 400 (1910).
SZÉPLIGETI, Mitt. Zool. Mus. Berlin, 1914, p. 172 (1914).

Belgian Congo: Walikale, January (J. Bequaert); Nala (Rodhain); Vele River (Rodhain). Four females given to me by Dr. Jos. Bequaert. This species is evidently widely distributed in equatorial Africa.

Iphiaulax consultus Szépligeti.

Ark. Zool., vol. 2, No. 14, p. 5 (1905).

Belgian Congo: Walikale, January (J. Bequaert). One female. As in several related species the antennæ are yellowish apically. I cannot be perfectly sure of the identification as the nervulus is distinctly postfurcal and Szépligeti does not mention this character although his figure shows it in this position. It is evident that this and a number of similar species, especially of the group Ipobracon, approach the genus Archibracon (*Pseudobracon*) in the position of the nervulus which is really the only diagnostic character. Possibly a close study will show that some other distinction can be drawn but I doubt this. Certainly in the identification of the species both genera must be taken into consideration.

Iphiaulax rugiventris Enderlein.

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 124 (1920) (*Bathyaulax*).

Two males from Bulawayo, Southern Rhodesia, December. This species resembles *I.trägårdi* Szépligeti.

Iphiaulax lucidus Szépligeti.

Ergebn. deutsch. Zent. Afrika Exped. 1907–8, vol. 3, p. 398 (1910) (*Hemibracon*).

Belgian Congo: Lubumbashi, Katanga, March (Mich. Bequaert) One female given me by Dr. Jos. Bequaert. The type locality is at the northern end of Lake Nyassa. The present example is the size of the type (20 mm.) but the ovipositor is longer than the body (25 mm.). The large triangular median area of the second segment reaches the middle of the segment and is prolonged to the apex as a stout carina; the lateral edge of the segment is distinctly notched just before the middle. The third segment bears a conspicuous transversely oval raised area on each side of the middle.

Iphiaulax melanosoma Brullé.

Hist. Nat. Ins. Hymén., vol. 4, p. 450 (1846) (*Vipio*).
CAMERON, Rec. Albany Mus., Grahamstown, vol. 1, p. 153 (1905) (*æthiopicus*).
CAMERON, Ann. South African Mus., vol. 5, p. 41 (1906) (*æthiopicus*).
SZÉPLIGETI, Ann. Mus., Nat. Hungarici, vol. 4, p. 554 (1906) (*Merinotus striatus*).
ROMAN, Ent. Tidskr., vol. 31, p. 131 (1910) (*Merinotus*).
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 405 (1914) (*Merinotus striatus*).
SZÉPLIGETI, Mitt. Zool. Mus. Berlin, vol. 7, p. 165 (1914) (*Merinotus striatus*).
BRUES, Ann. South African Mus., vol. 19, p. 61 (1924) (*æthiopicus*)

A female of this widespread species from Durban, Natal. It is a very characteristic form and is undoubtedly the one described by Brullé as *Vipio melanosoma*, twice since named by Szépligeti and Cameron.

Iphiaulax duodecimfasciatus Cameron.

Rec. Albany Mus., vol. 1, p. 154 (1905).
CAMERON, Ann. South African Mus., vol. 5, p. 55 (1906).
BRUES, ibid., vol. 19, p. 63 (1924).

One female. Rhodesia; Bulawayo, September (E. C. Chubb).

Iphiaulax havilandi Cameron.

Ann. South African Mus., vol. 5, p. 42 (1906).

Two females, Belgian Congo; Katanga, Elizabethville, November (Mich. Bequaert).

These specimens are entirely ferruginous except the antennæ and upper surface of the head which are black, but structurally they are identical with examples from more southern localities which have the thorax and abdomen always in part black. One female, Zululand; Nr. Eshowe, December (W. Haygarth). One female, Kenya Colony; Trans Nzoia, June (T. J. Anderson). This is black, except the thorax and front legs; the abdomen bears a pair of oblique yellowish lines on the second segment and a median one on the third and fourth segments.

Iphiaulax minyas Brues.

Ann. South African Mus., vol. 19, p. 43 (1924).

One female, agreeing exactly with the type. Natal; Upper Tongat, November (C. N. Barker).

Iphiaulax minyas Brues var. **kampalensis** var. nov.

♀. Length 13 mm.; ovipositor as long as the body. Head except spot on vertex, tegulæ, propodeum, mesopleura and legs, except front coxæ and hind tarsi, rufo-ferruginous. Antennæ, pro- and mesonotum, front coxæ and hind tarsi black. Wings black at base, fuscous toward apex; stigma yellow except at tip; most of first cubital cell yellowish, a hyaline band beyond the recurrent nervure and a hyaline streak along the second intercubitus. Head broader than thick, temples arcuately narrowed, occiput faintly excised medially; face smooth and shining, sparsely punctate below at the sides, clothed with conspicuous, sparse, erect, black hairs. Eyes rather large, oval, fully three times as long as the malar space. Palpi with the third joint noticeably swollen. Antennæ long and slender, scape one-half longer than wide, apex excised apically; basal joint of flagellum nearly twice as long as wide, following growing shorter, about quadrate near the middle and longer than wide apically. Mesonotum elongate, notauli rather weakly impressed; scutellar groove narrow, delicately crenulate. Propodeum, elongate, smooth and shining. Abdomen slender, elongate, more than three times as long as broad, of equal width at the apex of the second and third segments. First segment nearly twice as long as broad, the median lobe elongate oval, strongly longitudinally striate; lateral grooves very narrow, coarsely crenulate.

Second segment without median area, very evenly and closely longitudinally striate except in the large, elongate oval oblique lateral depressions where the striæ are oblique and more widely separated; base raised on each side of the middle to form narrow transverse smooth corners; second segment slightly shorter than wide at apex, the posterior margin bent forward strongly at the sides; suturiform groove also curved, very broad and deep, coarsely and evenly striate. Oblique grooves of third segment arising near the median line, not connected with the basal groove; very narrow at their origin but much widened behind, coarsely striate; surface of third segment closely striate like the second, the posterior border smooth, preceded by a finely crenulate groove; anterior corners large, smooth, convex as are also those of the fourth segment which has a broad striate groove at the base and a nearly smooth subapical one which precedes the smooth posterior border. Fourth segment striate medially except at apex, but smooth at the sides, the oblique grooves arising much farther from the median line than those of the third segment. Fifth, sixth and following segments smooth and polished. Sheaths of ovipositor slender, with very short hairs. Legs slender. Radial cell short, its apex far before the tip of the wing; first section of radius half as long as the second, third section barely as long as the other two; second transverse cubitus more than half as long as the second section of the radius, the second cubital cell noticeably widened apically; cubitus straight at the base; recurrent nervure long, entering the first cubital cell very near the apex; nervulus distinctly postfurcal.

Type from Uganda, Kampala, September.

The variety differs from the type in color and especially in lacking the striking wing maculation, but is very similar structurally.

This species resembles the widespread and variable *I. havilandi* Cameron in size, color and general habitus. However, the sculpture of the abdomen is very different. The middle lobe of the first segment is narrower, oval and striated throughout while the second segment lacks the oblique ridges of that species and the striæ are fine and longitudinal, not coarse and very oblique. It belongs to the section Merinotus.

Iphiaulax martinii Gribodo.

Ann. Mus. Civ. Genoa, vol. 14, p. 246 (1879) (*Bracon*).
CAMERON Ann. South African Mus., vol. 5, p. 57 (1906) (*robustus*).
CAMERON, Arch. Math. Naturvidens., vol. 30, p. 26 (1909) (*Goniobracon robustus*).

Szépligeti, Kilimandjaro-Meru Exped., vol. 2, p. 32 (1910) (*Goniobracon rubustus*).
Brues, Ann. South African Mus., vol. 19, p. 61 (1924).

Nine specimens, representing both sexes. Natal: Durban, February to April (C. N. Barker); Greenwood Park, October (D. R. Boyce); Umbogotwini, April (C. N. Barker). Zanzibar; Pemba Is., November (A. J. Snell). Kenya Colony; Juba River, Northern frontier district (J. O. Beven).

As noted by Cameron the nervulus in this species, as in a number of others in some of the groups of Iphiaulax, is clearly postfurcal. This is the case in Cratobracon also which has consequently been placed in both the Doryctinæ and Braconinæ and in Phanaulax which is otherwise an Iphiaulax.

Iphiaulax caracticus sp. nov.

♀. Length 15 mm.; ovipositor as long as the body. Pale yellow, the abdomen slightly darker; antennæ, head above antennæ, mesonotum, except the posterior half of the median lobe and hind legs beyond the base of the tibiæ black; sheaths of ovipositor black. Wings yellow at base, the yellow extending half way to the nervulus and further out along the costa; black beyond with the basal half of the stigma bright orange; basal two-thirds of first cubital cell and upper angle of third discoidal hyaline; a thin hyaline cloud along the second intercubitus. Head decidedly wider than thick, much narrower behind the eyes, the temples sharply rounded; vertex with an arcuate linear impression above the ocelli; front strongly excavated above each antenna; eyes distinctly emarginate internally, broadly oval, three times as long as the malar space which is indistinctly furrowed. Face closely punctate-rugose. Antennal scape compressed, one-half longer than thick, the apex emarginate externally; first flagellar joint twice as long as thick, second much shorter; joints near middle quadrate, those beyond becoming more elongate, considerably longer than wide. Mesonotum elongate, polished, notauli indicated faintly in front, obsolete behind; groove at base of scutellum strongly foveate. Pleuræ smooth, the propleura with a strong curved impression extending from the lower angle to the pronotum where it becomes a deep transverse groove; mesopleura with a strong oblique impression above just below the anterior wing, but without impression below. First segment of abdomen one-half longer than wide, not strongly narrowed at the base, its median area very coarsely and deeply striate; side pieces

narrow, smooth, the lateral carina sharp, horizontal. Second segment as long as wide at apex, slightly narrower at base; coarsely striate except basally at the sides and laterally in the impressions which are narrow and next to the lateral margin; base impressed at each side, but there is no discrete median area as the surface slopes off evenly to the lateral impressions; suture deep and wide, with strong, widely separated cross carinæ; lateral oblique grooves of third, fourth and fifth segments smooth; third and fourth segments deeply striate between the broad basal and apical furrows which are deeply and coarsely crenulate; of equal length, broader and shorter than the second segment, their posterior margins smooth, without margina impressed line, lateral areas smooth, large, triangular but only slightly convex; fifth segment almost covered by the coarsely crenulate basal and apical grooves, smooth in a narrow transverse band between them; sixth and seventh segments rather large, smooth. Ovipositor thickened beyond the middle, sharply curved like a fish-hook at apex where it bears a notch externally; sheaths gradually enlarged apically, triangularly widened at the extreme tip. Legs slender, spurs of hind tibiæ ferruginous. Radial cell not reaching to tip of wing; radius arising at the middle of the stigma, its first section very short; cubitus slightly bent at extreme base; stalk of second cubital cell scarcely one-third the length of the recurrent nervure; second cubital cell not widened apically, the intercubiti of equal length. Basal fourth of posterior wing pale, the radiellan cell with a very small pale spot at base.

Type from Natal; Bellair, January (E. C. Chubb).

This is a long slender species with the antennæ distinctly longer than the body. It will run to *I. martinii* Gribodo in my key to the South African species (1924) but is far more slender and otherwise widely different. It falls in the section Merinotus.

Iphiaulax jeanneli Szépligeti.

Rés. Sci. Voyage Alluaud, p. 173 (1914).

One female from Uganda; Kampala, November.

This agrees closely with Szépligeti's diagnosis of the species which came originally from the lower zone of Mount Kenya at an altitude of 1800 metres. A more complete description is appended. *I. nigroscutellaris* Szépligeti appears to be closely similar.

♀. Light yellowish fulvous, the head, except narrow orbits, anterior end of prothorax, mesonotum, tegulæ and scutellum black. Legs entirely yellow, except the apical half of the first and second and

the apical joint of the hind tarsi which are piceous. Wings deeply infuscated, the stigma and veins black. Head no wider than thick, eyes very prominent, temples obliquely narrowed, their hind angles rounded; occiput gently excavated. Frontal impression shallow. Face with a convex elevation at the center; faintly shagreened, sparsely punctate below at the sides. Eyes small, scarcely twice the length of the malar space which bears a rather distinct furrow. Antennal scape oval, not very strongly enlarged apically, nearly twice as long as broad; flagellar joints all longer than wide, the basal two or three twice as long as thick. Median lobe of mesonotum very strongly elevated anteriorly, the notauli deeply impressed on the anterior half; scutellar furrow broad, finely cross-striate. Propodeum smooth, faintly punctulate at the sides and with a few short longitudinal corrugations at apex. First segment of abdomen about as broad as long, median lobe broad, convex, longitudinally reticulate-striate; lateral grooves narrowed apically, strongly reticulate; lateral edge straight, carinate. Second segment strongly striate, without median area but with large triangular smooth corners each separated by a groove extending backward and outward from the basal middle and reaching halfway to the posterior angles; second segment about twice as wide as long. Suturiform articulation very broad, especially at the sides, strongly striate; oblique furrow of third segment crenulate, corners small; disk weakly punctate striate; about four times as broad as long at the middle; posterior edge smooth, not reflexed nor furrowed. Fourth and fifth segments faintly striate at base, smooth beyond, with a subapical crenulate furrow which is indistinct on the fourth, but very prominent on the fifth segment; both with a strong, crenate furrow at base. Sixth segment very small, smooth. Hypopygium not prominent; sheaths of ovipositor rather broad. Nervulus very slightly postfurcal. Radial cell short, not reaching the wing tip; third section of radius as long as the second and third; second scarcely twice as long as the second intercubitus; first section of cubitus straight; recurrent nervure entering the first cubital cell half its own length before the tip; cubitus straight at base.

Iphiaulax annulitarsis Cameron.

Arch. Math. Naturvidenskab, vol. 30, No. 10, p. 8 (1909).

This species which was described from Delagoa Bay is represented by a single male from Durban, Natal, October (A. L. Bevis).

Cameron says that the third section of the radius is twice the length

of the second, but I think this must be a misprint as this would be an unique condition in this group. In the present example the radial cell is moderately short, the third section of the radius distinctly longer than the second which is more than twice as long as the second intercubitus. As described by Cameron, the propodeum is strongly longitudinally wrinkled in a strip that occupies one-third the width of the propodeum. In color and structure the species is quite similar to *I. jeanneli* Szépligeti, but the stigma is yellow and as just mentioned the propodeum is striated.

The species has also been reported from Tanganyika Territory by Szépligeti.

Iphiaulax microphthalmus sp. nov.

♀. Length 6.5 mm.; ovipositor 2.5 mm. Pale fulvous yellow; antennæ black; abdomen darker at the sides of the second segment and at apex. Wings dull yellowish at the base, shading into light fuscous beyond the middle; in the hind wing the yellow extends farther along the anterior border than behind; stigma black. Head broader than thick, the eyes strongly protuberant when seen from above; temples strongly arcuately narrowed behind the eyes, the occiput feebly excavated; groove surrounding the ocelli continued forward as a V-shaped line; frontal impression single, deepest medially; face minutely rugose; malar space nearly as long as the small, elongate eye; palpi very slender. Antennal scape one-half longer than wide, expanded apically, emarginate outwardly at tip and slightly produced at tip below; basal joints of flagellum one-half longer than wide, those beyond quadrate or slightly transverse, mesonotum with distinct notauli, the median lobe strongly raised; scutellar groove crenulated. Propodeum short, with a pair of indistinct grooves basally near the middle. Abdomen short and broad, almost globose; first segment a little broader than long, the median lobe semicircular, convex, strongly striated, at apex tubercularly produced medially; lateral groove broad, carinate on the edge and coarsely cross-striated. Second and third segments together one-half wider than long, longitudinally striate-reticulate, suture coarsely crenulate, broad, bifurcate laterally, the anterior branch narrower, enclosing rather large, nearly flat corners; lateral triangles of second segment defined inwardly by a sharp oblique carina and externally by an oval impression; fourth and fifth segments highly convex, each with a deep striate impression at base and a subapical groove much deeper and broader on the fifth; sculptured like the second and third. Hypopygium triangular, not

prominent; ovipositor sheaths gradually expanded to their rounded tips. Legs unusually short and stout, especially the hind pair, clothed like the body with shining fulvous hairs which are especially dense on the hind tibiæ and tarsi. Radial cell rather short, not attaining the wing tip; third section of radius as long as the other two; cubitus straight at base, nervulus interstitial; second transverse cubitus half as long as the second section of the radius, recurrent nervure entering the first cubital cell one-half its length before the tip.

Type from Uganda; Butembe, March (E. Hargreaves).

This species belongs to the section of Iphiaulax, *sensu stricto*. It forms more or less of a transition toward Chelonogastra (*Monocoila*).

Iphiaulax spilonotus Cameron.

Rec. Albany Mus. Grahamstown, vol. 1, p. 165 (1905).
BRUES, Ann. South African Mus., vol. 19, p. 62 (1924).

Thirteen specimens, all females. Natal; Durban, October to May (C. N. Barker), Durban, October to April (A. L. Bevis), Upper Tongat, November (C. N. Barker), Winklespruit, January (C. N. Barker), Widenham, December (A. L. Bevis).

There is practically no variation in sculpture but the color of the body is variable and all are much lighter than the specimen described by Cameron. The thorax is often entirely red, except for a mark on the propleura which is nearly always present. The black on the head may be so reduced that there remains only a large spot on the vertex; when the head is extensively black the orbits always remain very narrowly yellowish red. The length varies from 8.5 to 15 mm.

Iphiaulax incisus Brullé.

Hist. Nat. Ins. Hymén., vol. 4, p. 427 (1846) (*Bracon*).
CAMERON, Ann. South African Mus., vol. 5, p. 47 (1906).
BRUES, ibid., vol. 19, p. 64 (1924).

One female of this pecies as I have identified it (*vide supra*). Rhodesia; Bulawayo, September.

Iphiaulax odontoscapus Cameron.

Rec. Albany Mus., vol. 1, p. 154 (1905).

Seven females from Durban, Natal (C. L. Barker) taken from October to April.

This species appears to be very similar to *Bracon rugosus* Brullé in color and sculpture, but I cannot reconcile Brullé's reference to the elevated median lobe of the mesonotum and broad deep parapsidal furrows, which renders it probable that the two species are not congeneric.

Iphiaulax tigrinus Szépligeti.

Kilimandjaro-Meru Exped., vol. 2, p. 33 (1910).

A female from the Eele river, Congo (Rodhain) from Dr. Jos. Bequaert. The nervulus is distinctly postfurcal.

Iphiaulax pandora Brues.

Ann. South African Mus., vol. 19, P. 57 (1924).

This species is probably similar to the type of Cameron's genus Holcobracon (Arch. Math. Videns., vol. 30, No. 10, p. 20, 1909) but to judge from the description of *H. erythraspis* cannot be that species on account of the color and short ovipositor.

Two females. Rhodesia; Bulawayo, August and September (E. C. Chubb).

Iphiaulax lativentris Cameron.

Ann. South African Mus., Vol. 5, p. 51 (1906).
Brues, ibid., vol. 19, p. 63 (1924).

One female. Natal; Greenwood Park, Durban, October (D. R. Boyce).

Iphiaulax nataliensis Szépligeti.

Termes. Füzetek, vol. 24, p. 395 (1901).
CAMERON, Rec. Albany Mus., Grahamstown, vol. 1, p. 150 (1905) (*basimacula*).
SCHULZ, Spolia Hymenop. p. 140 (1906) (*inacceptus*).

One female from Southern Rhodesia; Sawmills, December.

Structurally this species is very similar to *Iphiaulax erythraspis* Cameron, the type of *Holcobracon* Cameron and to *Iphiaulax pandora* Brues both of which have the posterior angles of the fifth abdominal segment noticeably produced. From the former it differs by the short ovipositor and from the latter by the color of the wing which lacks the blood red costa and stigma. From *I. lativentris* Cameron which it resembles much in habitus, it differs by the produced angles of the fifth segment.

Iphiaulax decemmaculatus Szépligeti.

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., 1907–08, vol. 3, p. 404 (1910).

One male. Rhodesia; Bulawayo.

The male lacks the thickened hind legs of the female and the hind coxæ are twice as long as thick. The four round dark clouds in the wing are placed at the base of the cubitus, below the tip of stigma in the radial cell, in the middle of the second cubital cell and in the posterior part of the lower discoidal cell; the hind wing lacks a pre-apical cloud.

Iphiaulax cephalotus Szépligeti.

Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 33 (1910).

This species was described from the male and I have a female from Kericho, Lumbiva district, British East Africa (C. H. Dobbs). It bears a label indicating an altitude of 6,500 feet with the note "very common at Kericho."

The female measures 8 mm. with the ovipositor nearly as long as the abdomen. The striation of the abdomen is uniformly fine, and the suturiform articulation is strongly bowed backwards at the sides, broad behind the anterior corners of the third segment, but very narrow in front of these; the lateral basal corners of the second segment are nearly smooth and deeply obliquely impressed inwardly behind; together the second and third segments are as long as the apical width of the third.

Iphiaulax basiornatus Cameron.

Arch. Math. Naturvidens., vol. 30, No. 10, p. 17 (1909).

One male, Natal; Durban, October (C. N. Barker). In color and general form this species is a replica of *I. phosphor* Brues, but the third, fourth and fifth tergites are densely and coarsely striate.

Archibracon Saussure.

Grandidier, Hist. Madagascar, vol. 20, Hyménop., pl. 14, fig. 13 (1892).

Numerous African species of this genus have been described by Cameron as Exothecus and by Szépligeti as Pseudobracon. They are extremely variable in color and extremely similar structurally so

that there seems to be no question that the number of species will finally be greatly reduced. Among some twenty-five specimens I have been able to recognize four species with some degree of satisfaction.

Archibracon pulchripennis Cameron.

Ann. South African Mus., vol. 5, p. 73 (1906) (*Exothecus*).

Four females, all from Durban, Natal (C. N. Barker) February to March.

Archibracon servillei Brullé.

Hist. Nat. Ins. Hymén., vol. 4, p. 418 (1846) (*Bracon*).
Szépligeti, Gen. Insect., fasc. 22, p. 49 (1905) (*Pseudobracon africanus*).
Cameron, Rec. Albany Mus., Grahamstown, vol. 1, p. 156 (1905) (*Exothecus tibialis*); p. 167 (*Exothecus canaliculatus*).

Seven females and five males. Natal: Durban, December (A. L. Bevis); Doonside, January (A. L. Bevis); Widenham, January (A. L. Bevis); Durban, March and April (C. N. Barker); Winklespruit (C. N. Barker); Weenen, December to January (H. P. Thomasset). Uganda: Kampala, September (C. C. Gowdey). Kenya Colony: Juba River, Northern frontier district, July (J. O. Beven).

The size varies greatly in both sexes, the females ranging from 13–20 mm. in length and the males from 10–14 mm.

Archibracon elizabethæ Cameron.

Ann. South African Mus., vol. 5, p. 72 (1906) (*Exothecus*).

The yellow on the wings is more extensive in this species and includes a complete band below the stigma and a spot on the hind wing beyond the middle. It is probably only a form of the widespread and common *A. servillei.* Specimens of this type are from Natal: Durban, February and March (A. L. Bevis); Widenham, December (A. L. Bevis) and Doonside, January (A. L. Bevis).

Pseudobracon fasciatus Szép. (Mitt. Zoöl. Mus. Berlin, 1914, p. 191) is probably a synonym also.

Archibracon cameroni Brues.

Ann. South African Mus., vol. 19, p. 78 (1924).

Cameron, ibid., vol. 5, p. 73 (1906) (*Exothecus flaviceps*, non *Archibracon flaviceps* Sauss, 1892).

Three specimens. Natal; Winklespruit, December (C. N. Barker); Ualab, September; Durban, March (C. N. Barker).

Archibracon megacephalus Szépligeti.

Mitt. Zool. Mus. Berlin, vol. 7, p. 190 (1914) (*Pseudobracon*).

A female from the Belgian Congo; Lubatu, January, (Jos. Bequaert). Szépligeti refers to the large size of the head, but does not mention the peculiar form of the face which is concave, with the edge of the clypeus only very slightly excavated. The mandibles are extremely large, evenly curved and with two large teeth at the apex; they set very far apart as the head is not narrowed below the eyes. The form of the head, mandibles, etc. is very much like that of Euurobracon, but the abdomen is like that of the species of Pseudobracon.

Plaxopsis Szépligeti.

Ark. Zool., vol. 2, No. 14, p. 1 (1905).

Plaxopsis magnificus Enderlein.

Arch. Naturg., Jahrg. 84A (1918) Heft 11, p. 77 (1920) (*Ipobracon*).

A specimen from Tanganyika Territory agrees closely with Enderlein's description and I think he must have overlooked the frontal projection characteristic of Plaxopsis. I had regarded the present example as a new species and drew up a description of it which contains characters not referred to by Enderlein. This is reproduced below.

♀. Length 12 m.; ovipositor 10 mm. Rufo-ferruginous; head yellow; antennæ, legs including coxæ and sheaths of ovipositor black; base of anterior tibiæ yellowish; apex of abdomen more or less yellow. Wing black from base to base of stigma and nervellus; pale yellow beyond except for a black border extending from apical part of the radial cell along the wing margin to just below the middle of the second cubital cell; this band is narrowed below the second intercubitus; stigma entirely yellow; hind wing black with a pale spot anteriorly beyond the middle which does not extend to the posterior margin. Head sparsely clothed with pale hairs; legs with dense bristly hairs, golden on the front legs and black on the others. Head smooth and

shining, the face faintly punctulate; facial projection rather narrow, acutely rounded at tip. Malar space one-third the length of the oval eye, indistinctly furrowed; antennal scape simple, not produced at apex; flagellar joints at base quadrate, transverse beyond. Thorax, including pleuræ, highly polished; parapsides clearly indicated, the middle lobe elevated anteriorly; scutellar groove delicately crenulate. First segment of abdomen slightly longer than broad, the median lobe not very strongly elevated, smooth except for a feeble median carina; the lateral depressed area with a marginal carina and another inward from this. Second and following segments polished. Second twice as wide as long, wider behind with a small smooth basal area prolonged into a carina which nearly attains the hind margin; its surface sparsely irregularly longitudinally striated except at apex; lateral elevations very small; base with an impression at each side of the middle; side with a large elongate impression next to the lateral margin, bounded internally by a curved carina. Third segment broader and shorter than the second; basal groove crenulated; lateral angles rather large, separated by oblique crenulate grooves; surface smooth; apex without a marginal impressed line; following segments smooth, the fourth and fifth each with a narrow crenulate basal line. Sides of stigma of equal length; nervulus curved, faintly postfurcal; radial cell reaching to the tip of the wing; cubitus bent at base; second section of cubitus three times as long as the second intercubitus.

Tanganyika; Amani, December (A. H. Ritchie).

This is a most remarkable mimic of *Iphiaulax calopterus* Szépligeti which it resembles exactly in the rather unusual wing pattern. Aside from the frontal horn it differs, however, in several particulars. The face is smooth and shining, not rugose; there is a distinct median area on the second segment and there is no punctate line before the hind edge of the third and fourth segments; also the third segment is smooth, not rugose medially.

Plaxopsis roseogaster sp. nov.

♀. Length 11–12 mm. Thorax, antennæ and legs black, most of the front femora and tibiæ golden brown; head yellow; abdomen including venter pale magenta or pink; wings black, including the stigma, the fore pair with a faint whitish streak below the stigma and an elongate pale cloud about the second intercubitus; hind wings entirely black. Head almost as thick as broad; the temples full, rounded. Eyes but little longer than broad, twice as wide as the malar space. Antennæ as long as the body; scape simple; basal

joints of flagellum a little longer than wide; apical joints transverse. Head polished above, with a distinct median groove below the ocelli; face shining, faintly punctulate; facial projection small, subtriangular, rounded at tip. Thorax entirely smooth and polished; notauli shallow but quite distinctly impressed anteriorly, the median lobe elevated; basal groove of scutellum punctate. First abdominal segment one-third longer than wide at tip; median lobe moderately convex, obsoletely longitudinally striate and with a weak median carina behind; side pieces narrow, margined at the side by two closely approximated carinæ. Second segment strongly widened to apex where it is twice as broad as long; basal area small, triangular, shining, not strongly raised, prolonged to apex of segment as a more or less distinct median carina; basal lateral areas small, shining; surface with widely separated longitudinal striations which do not reach the apex; basal impression small, deep; lateral ones oval moderately impressed, bordered inwardly by a nearly straight carina. Third segment broader and shorter than the second, fully three times as wide as long; first suture broad, crenulate; anterior corners triangular, rather large, separated by a narrow crenulate furrow; surface smooth, without any impressed line before apex. Following segments smooth; fourth and fifth with a narrow crenulate furrow at base. Tibiæ and tarsi densely bristly pubescent. Sides of stigma about equal, radial cell extending to wing-tip; cubitus bent at base; second cubital cell rather strongly widened apically; nervulus very slightly postfurcal. Sheaths of ovipositor rather densely short pubescent.

Type and one paratype from Uganda; Entebbe, September, and Mwera, August (C. C. Gowdy).

The coloration of the abdomen is very conspicuously pink rather than red.

This species has the color of *P. schultzei* Szépligeti and wing pattern of *P. sjöstedti* Szépligeti and is structurally similar to both although I think distinct from either. From the second it differs by the pale magenta colored abdomen, entirely black antennæ and shorter abdominal petiole, and from *P. schultzei* by the shorter ovipositor, different wing pattern and the absence of an apical groove on the third tergite.

Plaxopsis büttneri Szépligeti.

Mitt. Zool. Mus. Berlin, vol. 7, p. 159 (1914).

A female Uganda, Entebbe, October (C. C. Gowdey).

Schiztobracon Cameron.

Ann. South African Mus., vol. 5, p. 70 (1906).
Roman, Ent. Tidskr., vol. 31, p. 138 (1910) (*Tricœlopyge*).

Schiztobracon trisinuatus sp. nov.

♀. Length 7.5 mm.; ovipositor 2 mm. A very slender species differing from the genotype by its elongate abdomen, very elongate thorax and long legs. Light fulvous yellow, the head and thorax paler and with black markings as follows: antennæ, head above, except for narrow orbits, pro and mesosternum, tegulæ and mesonotum, except the posterior half of the median lobe. Legs fulvous, the four posterior tarsi and the hind tibiæ, except base, black, wings black, basal half of stigma bright yellow; an irregular pale streak in the first cubital cell and another along the second intercubitus. Head as thick as wide, the temples arcuately narrowed behind the eyes; front not excavated, with an impressed fine line medially below the ocelli. Eye oval, about three times as long as the distinctly grooved malar space; face shining, nearly smooth. Antennæ long, slender; scape large, oval, one-half longer than broad; first two flagellar joints twice as long as thick, the following growing shorter, but all are longer than wide. Palpi slender; pronotum with a deep, crenate, transverse furrow, the upper edge straight; mesonotum very elongate; notauli well impressed anteriorly. Scutellum with a broad crenulate furrow at base. Propodeum smooth and polished, without sculpture. Abdomen more than two and one-half times as long as broad, but little widened behind the base of the second segment. First segment one-fourth longer than wide, its median lobe large, extending nearly to the base, coarsely rugose; lateral furrows very narrow behind. Second to fifth segments of nearly equal length; sixth and following retracted, not visible. Second segment one-third broader than long, with a large elongate triangular median area extending nearly to the apex, defined by broad, obliquely striate furrows; lateral impressions linear, shallow, parallel with the sides of the median area; surface, including median area, reticulate. Third, fourth and fifth reticulate like the second; suturiform articulation broad, crenulate, oblique furrow narrower, crenulate, the corners large, triangular, internally smooth; apex simple, not furrowed; fourth segment like the third, with a crenulate furrow at base; fifth with a narrower crenulate furrow at base; apex weakly incised near each side and again at the middle, the edge smooth, not reflexed, rimmed, nor denticulate. Radius arising at the middle

of the stigma; radial cell rather long, but ending considerably before the wing tip; cubitus straight at the base; nervulus interstitial; recurrent nervure entering the first cubital cell very near to the tip.

Type from Umbilo, Natal, October (A. L. Bevis); paratype from Durban, October (C. N. Barker).

This species differs considerably from *S. latilobatus* in the sculpture of the abdomen; the area on the second segment is triangular instead of shield-shaped and the incisions on the apex of the fifth segment are not nearly so deep. Nevertheless it will be sought for here on account of the presence of three incisions on the fifth segment, a fundamentally different arrangement from that of Cœlodontus Roman which has the fifth segment incised twice, with a median projection between.

Odontogaster Szépligeti.

Ann. Mus. Nat. Hungarici, vol. 4, p. 551 (1906).

Artificial Key to the African Species.

1. Abdomen red.......................................2.
   Abdomen black, entirely or in great part.................11.
2. Stigma black; sometimes paler when wings are lightly colored, but never bicolored.................................3.
   Stigma bicolored, yellow at base and black apically.........9.
3. Legs red, at most the hind pair partly dark.................4.
   Legs black, all three pairs wholly so or in great part.........8.
4. Head entirely reddish, at most the middle of the vertex black.5.
   Head black above, hind legs partly black. .*O. guineensis* Szép.
5. Abdomen slender, acutely rounded at apex; small species (4 mm.) *O. minor* Szép.
   Abdomen stout, apex broadly rounded; larger species (6–8 mm.)...6.
6. Ovipositor half as long as the abdomen; cubitus straight at the base; recurrent nervure entering the first cubital cell. *O. uniformis* Brues.
   Ovipositor one-third as long as the abdomen; cubitus broken at base; recurrent nervure interstitial.......................7.
7. Vertex black at middle; hind legs not brown. *O. madagascariensis* Szép.
   Vertex entirely reddish; hind legs reddish-brown. *O. camerunensis* Szép.
8. Small species, 5 mm.; ovipositor 1 mm.; wings and stigma pale brown; thorax mostly black.................*O. nana* Szép.

Larger species, 7 mm.; ovipositor over 2 mm.; wings and stigma black; thorax red.................. *O. atripes* sp. nov.
9. Ovipositor as long as the body............ *O. caudata* Szép.
Ovipositor much shorter than the abdomen.................10.
10. Ovipositor two-thirds as long as the abdomen..*O. spinosa* Cam.
Ovipositor one-half as long as the abdomen..*O. abyssinica* Szép.
11. Legs red, hind pair somewhat infuscated......*O. variegata* Szép.
Legs black...12.
12. Thorax entirely red; ♀ 9 mm. in length......*O. bicolor* Szép.
Thorax black above; ♂ 5 mm. in length..*O. nigripes* Szép.

Odontogaster atripes sp. nov.

♀. Length 7 mm.; ovipositor half as long as the abdomen. Rufo-ferruginous, the antennæ, palpi and legs black except the extreme base of the coxæ; head black above from the antennæ almost to the occipital margin. Wings black brown, the stigma piceous; first cubital cell with a faint paler streak; apex of second discoidal cell with a small hyaline spot; base of third discoidal cell with a larger one; second intercubitus with a narrow hyaline margin. Head entirely smooth above and behind, sparsely punctate on the cheeks, more densely so at the sides of the face and with the center of the face delicately rugulose. Ocelli surrounded by an impressed line. Antennæ shorter than the body; rather stout, flagellar joints beyond the first two scarcely longer than broad. Malar space one-fourth as long as the eye, with furrow. Mesonotum smooth and polished; notauli distinct in front, obsolete behind; scutellar groove rather finely crenate. Propodeum highly polished above. Pleuræ smooth and shining; no mesopleural furrow; sides of propodeum finely sparsely punctate. First abdominal segment but little longer than wide; median portion evenly convex and very coarsely reticulate, each area very clearly marked; lateral grooves smooth, but with numerous short carinæ that extend into them for a short distance from the reticulate median portion. Second segment coarsely but more irregularly reticulate; half as long as wide at apex; with a small nearly smooth median basal area continued to the apex of the segment as a median keel; lateral grooves convergent; apical suture deeply crenulate, nearly straight. Third segment sculptured like the second and a little shorter, three times as wide as long; its apical suture deeply impressed and coarsely striate. Fourth as long as the third and slightly wider, similarly sculptured with its apical suture deep and finely striated. Fifth longer, similarly sculptured, obtusely rounded at apex, the lateral

teeth less prominent than the median ones. Nervulus interstitial; radial cell almost attaining the wing tip; first section of radius less than one-third as long as the second, third as long as the other two; cubitus faintly curved, at base, arising at the basal third of the basal vein; second cubital cell scarcely widened at tip; recurrent nervure entering the first cubital cell distinctly before its tip.

Type and two paratypes from British East Africa: Kericho, September 1, 1913 (C. M. Dobbs); without special locality or date (C. M. Dobbs); Entebbe, Miwera, August 26, 1912 (C. C. Gowdey).

Odontogaster nana Szépligeti.

Mitt. Zool. Mus. Berlin, vol. 7, p. 161 (1914).

Two specimens possibly of this species from the Belgian Congo (J. Bequaert) have the thorax entirely red. The legs in one are partly and in the other entirely black. Quite probably they are males of an undescribed species.

Odontogaster nigripes Szépligeti.

Mitt. Zool. Mus Berlin, vol. 7, p, 161 (1914). ♂.

A female of this species from Kampala, Uganda, November 17, 1915, agrees with Szépligeti's description of the male.

Odontogaster spinosa Cameron.

Arch. Math. Naturvidens., vol. 30, p. 22 (1909).

Durban, Natal, Feb. 19, 1914 (E. C. Chubb) and April 17, 1920. (C. N. Barker) both forwarded from the Durban Museum; British East Africa, Masai Reserve (T. J. Anderson), from the Imperial Bureau of Entomology.

Odontogaster minor Szépligeti.

Ann. Mus. Nat. Hungarici, vol. 4, p. 551 (1906).

Three specimens from Umbilo, Durban, Natal, July–October (A. L. Bevis).

Odontogaster uniformis Brues.

Ann. South African Mus., vol. 19, p. 70 (1924).

Zanzibar, near Mazi Moja, Aug.–Sept. 1924 (H. J. Snell), forwarded by the Imperial Bureau of Entomology.

Mesobracon Szépligeti.

Termes. Füzetek, vol. 25, p. 46 (1902).
Szépligeti, *ibid*, *t. c.* p. 44 (1902) (*Macrobracon*).
Cameron, Ann. South African Mus., vol. 5, p. 75 (1906) (*Telerda*).
Turner, Ann. Mag. Nat. Hist. (8), vol. 20, p. 245 (1917).
Brues, Ann. South African Mus., vol. 19, p. 140 (1924).

Key to Species.

1. Stigma black . . . . 2.
   Stigma pale, except at extreme tip . . . . 5.
2. Abdomen in greater part black; median area of second abdominal segment lanceolate . . . . *M. truncatus* Szép.
   Abdomen yellow or red, median area very broad anteriorly . . 3.
3. Thorax black above . . . . 4.
   Thorax entirely reddish . . . . *M. punctatus* Szép.
4. Fore wing with a large hyaline spot on the second transverse cubitus . . . . *M. elegans* Szép.
   Wings entirely black . . . . *M. atripennis* Szép.
5. Entirely black, except base of abdomen; basal two-thirds of fore wing entirely pale yellow . . . . *M. niger* Szép.
   Partly yellow; yellow at base of wing less extensive . . . . 6.
6. Fore wing with a distinct pale crossband beyond the middle . . 7.
   Fore wing with pale spots, but without crossband beyond middle . . . . 10.
7. Abdomen black at apex . . . . 9.
   Abdomen pale at tip . . . . 8.
8. Thorax and four posterior legs black . . . . . . *M. pedalis* sp. nov.
   Thorax and legs, except hind tarsi, reddish . . . . *M. similis* Szép.
9. Only the sixth segment black; propodeum without distinct median groove . . . . *M. pulchripennis* Szép.
   Fifth segment black also . . . . *M. guineensis* Szép.
10. Wings distinctly yellow on basal third or fourth . . . . 11.
    Wings without yellow at base, mesonotum pale. *M. nigriceps* Cam.
11. Apical segments of abdomen black . . . . 12.
    Apical segments of abdomen reddish . . . . *M. luteus* Cam.
12. Only the sixth segment black . . . . 13.
    Fifth and also sometimes the more basal segments black . . . . 14.
13. Mesonotum pale . . . . *M. nigricornis* Szép.
    Mesonotum with three black spots . . . . *M. trimaculatus* Szép.

14. Second and following segments of abdomen in part black; mesonotum pale. . . . . *M. maculiceps* Cameron.
First four abdominal segments wholly yellow. . . . . 15.
15. Propodeum smooth, with scattered shallow punctures; nervulus strongly postfurcal (by half its own length). . *M. capensis* Szép.
Propodeum with irregular longitudinal reticulations; nervulus less strongly postfurcal. . . . . *M. minor* sp. nov.

Mesobracon niger Szépligeti.

Ann. Mus. Nat. Hungarici, vol. 4, p. 596 (1906). ♂.

A single female from Durban, Natal, March 25, 1917 (C. N. Barker).

The species which was described from a male from "Africa" in the collection of Professor Poulton in Oxford is evidently a South African form. The female is somewhat smaller than the type ♂. The first segment of the abdomen and the triangular central part of the second are yellow although there is no yellowish median line on the following segments. The striking coloration of this species is almost exactly similar to that of certain species of Iphiaulax and Braunsia.

Mesobracon minor sp. nov.

♂. Length 7 mm. Fulvous, marked with black as follows: antennæ; head above the antennæ and behind the eyes and more or less of the anterior orbits; prothorax below, mesonotum, scutellum, large central spot on mesopleura; fifth and six abdominal segments, and hind tarsi. Wings rather dilute fuscous, stigma yellow with black apex; light yellowish from base to beyond middle of submedian cell; with a hyaline streak from the base of stigma to the upper angle of the second discoidal cell and another along the second transverse cubitus; veins dark except on the yellow portion. Head twice as wide as thick, greatly narrowed behind the eyes and broadly shallowly excavate behind; malar space one-third as long as the eye; entirely shining, including the face. Antennal scape oval, with bristly hairs below; basal joints of flagellum quadrate, becoming slightly transverse apically. Mesonotum shining; middle lobe very convex; parapsidal furrows deep, much widened behind where they approach one another but are separated by a distinct smooth ridge. Propodeum not distinctly furrowed medially, its surface shallowly and irregularly longitudinally reticulate striate. Pleuræ entirely smooth and shining; no

mesopleural furrow. Abdomen above with the usual coarsely reticulate sculpture, the sutures very deep and crenulate, except the first; basal segment very strongly elevated medially, at the side with a broad smooth furrow just inside the lateral edge; second segment as broad as long, the apex one-third wider than the base, the median area triangular, but not quite narrowed to a point behind; third as long as the second, transverse and slightly widened behind; fourth and fifth strongly transverse and slightly narrower behind, each clearly shorter than the third; abdomen without a median carina, but the sculpture along the median dorsal line is obsolete on segments four and five and weakly striate on the second and third. Radius arising just beyond the middle of the stigma, first section one-third as long as the second, third equalling the other two; radial cell not attaining the wing tip; nervulus postfurcal by one-fourth its length; cubitus arising from the basal vein, not curved downwards at base; first transverse cubitus oblique; second cubital cell slightly widened apically, one-third shorter above than below, outer edge only half as long as the upper; recurrent nervure entering the first cubital cell; submedian cell of hind wing less than one-fourth as long as the median.

Type from Umbilo, Durban, Natal, Dec. 15, 1919 (A. L. Bevis); paratype the same, but Dec. 18, 1919.

This species resembles *M. capensis* of which I have seen only the female, but is very much smaller, with differently sculptured propodeum, less strongly postfurcal nervulus, longer second cubital cell and shorter submedian cell in the hind wing. From *M. concolor* Szép. it differs in the sculpture of the propodeum as well as in color.

Mesobracon capensis Szépligeti.

Mitt. Zoöl. Mus. Berlin, vol. 7, p. 189 (1914).

Two females, Durban, Feb. 12 and April 19, 1919 (C. N. Barker).

Mesobracon pedalis sp. nov.

♀. Length 13–14 mm. Head, including palpi, fore legs and lower part of prothorax yellow; thorax black with a fulvous horizontal stripe on mesopleura below; abdomen entirely rufous; ocellar tubercle and four posterior legs black. Wings yellowish on basal third; black beyond, with a complete yellowish crossband below the stigma and a pale yellowish oval subapical spot as high as the length of the second section of the radius and nearly as long. Hind wing yellowish at base

and with an incomplete pale subapical band below the band on the fore wing. Antennæ dark, distinctly reddish toward apex. Head more than one and one-half times as broad as thick, the eyes strongly bulging and the occiput sharply narrowed. Vertex subopaque, head behind and below the eye shining; face shining, with a few scattered punctures; malar space one-third as long as the eye. Antennal scape about twice as long as thick; flagellar joints, except first distinctly transverse. Mesonotum strongly convex, trilobed; notauli deep, but not at all crenulate; surface highly polished, smooth. Propodeum with a distinct median groove, shining, entirely smooth except for a few very faint punctures. Pleuræ smooth; mesopleura without trace of furrow. Abdomen irregularly longitudinally striate, distinctly reticulate only near the posterior margins of the segments. Basal and upper surfaces of first segment forming a right angle, the upper surface irregularly reticulate, side with a sinuous carina inside the lateral margin. Second segment as long as the third which is twice as wide as long; sutures deep, their striations continuous with those of the basal portions of the segments. Sixth segment armed with five or six minute delicate spinose projections at each side of the posterior edge; seventh with the angles spinose and with a spinule near the angle. Sheaths of ovipositor stout, hairy, one-third as long as the abdomen. Radial cell ending well before the tip of wing; first section of radius nearly half as long as the second which is as long as the third; nervulus postfurcal by one-third its length; cubitus straight at base; second cubital cell widened apically, the top less than twice as long as the apex; first intercubitus and recurrent nervure parallel, the latter entering the first cubital cell near its apex.

Type and paratype from Uganda; Entebbe, August and November, 1912 (C. C. Gowdey).

This is a large and especially handsome species. The abdomen is more clearly striate than usual. In wing pattern it resembles *M. similis* and *M. pulchripennis*, from the former and also from all others with maculate wings it differs by the black legs and from the latter by the presence of a median groove on the propodeum.

Curriea Ashmead.

Bull. U. S. Nat. Mus., vol. 23, p. 50 (1900).

Curriea simplex sp. nov.

♂. Length 7 mm. Head and thorax, including coxæ, black; tegulæ, legs and abdomen rufo-ferruginous. Base of wings yellowish

hyaline; beyond the basal vein pale fuscous with dark veins; a subhyaline band below the base of the stigma; stigma yellowish red at base, dark apically; hind wing subhyaline at base, light fuscous apically. Head, seen from above somewhat less than twice as wide as thick, rounded on the sides, the occiput deeply, broadly emarginate; frontal excavation slight. Eyes very large, weakly emarginate at a point considerably above the antennæ; front broad, but the face much narrowed, little more than one-fourth the width of the head; face wider above and below, smooth medially, rugulose at the sides; malar space extremely short; head above and behind smooth and shining. Antennæ stout, the middle of the flagellum thicker than the base; first three flagellar joints distinctly longer than thick, following growing quadrate or slightly transverse. Notauli shallow, but quite distinct anteriorly. Scutellar groove minutely crenulate. Pleuræ highly polished; mesopleura with a small foveate impression above the middle. Propodeum short, but little curved in profile. First five segments of abdomen coarsely sculptured; first segment as broad as long, the median lobe coarsely reticulate; sides broad, smooth, widened behind and with a strong carina along the middle line; second to fourth segments deeply closely rugose punctate; fifth more sparsely so. Second segment nearly twice as broad as long, convex medially at the base, but without a raised area; anterior corners smooth, convex, also a band along the front and lateral margins. Third segment wider and shorter than the second, nearly four times as broad as long; suture at the base broad, deeply crenulated; oblique furrow narrow, crenulate, the anterior corner small, convex, shining; its surface only slightly convex, the posterior margin smooth and separated by an indistinct furrow. Fourth and fifth segments each nearly as long as the third, increasingly convex, with a crenulate furrow at base and small, convex, shining, separated anterior corners; each with a coarsely punctate apical furrow, their posterior margins smooth; following segments almost entirely retracted, smooth. Legs short and stout. Radial cell not attaining the wing-tip; radius arising at the middle of the stigma, its third section scarcely as long as the second; cubitus arising at the upper third of the basal vein; nervulus interstitial; recurrent nervure received just before the tip of the first cubital cell; apex of second cubital cell one-third as long as the upper side. Body and legs clothed with rather long sparse thin white hairs.

Type from Southern Rhodesia; Bulawayo, August (E. C. Chubb).

This species differs from all other members of the genus that I have seen in the entirely normal venation as neither the nervulus nor other

veins surrounding the third discoidal cell are bent or distorted. I cannot, however, be sure that this condition does not exist in any described species as these characters have been commonly omitted from descriptions. Otherwise it may easily be distinguished by its color and sculpture.

Chelonogastra Ashmead.

Proc. U. S. Nat. Mus., vol. 23, p. 139 (1900).
Roman, Entom. Tidskr., 1910, p. 133 (1910) (*Monocoila*).
Enderlein, Arch. Naturg., Jahrg. 84A, Heft 11, p. 111 (1920) (*Ectemnoplax*).
Turner, Ann. Mag. Nat. Hist. (9), vol. 10, p. 272 (1922).
Brues, Ann. South African Mus., vol. 19, p. 72 (1924).

While the manuscript of my paper (*vide supra*) was in the hands of Dr. Péringuey at the South African Museum awaiting publication Turner described two species of Monocoila (*M. signata, M. innotata*) from the Cape Province. His *M. signata* was not represented in my collections, but *M. innotata* may have to replace *C. elongatula* when opportunity presents itself to compare the types. As nearly as I can distinguish them, the African species may be separated as follows. *C. lurida* Enderlein, cannot be placed as the description is too incomplete.

1. Base of cubital vein straight.............................2.
   Base of cubital vein curved..............*C. pectoralis* Holmg.
2. Radial cell nearly attaining the tip of the wing; face shining; fourth and fifth segments much more finely sculptured than the second and third..................*C. orbiculata* Brues.
   Radial cell ending considerably before the tip of the wing....3.
3. Face shining, shagreened or punctate.......................4.
   Face opaque, finely punctured.............*C. signata* Turner.
4. Suturiform articulation strongly arched forward on the disc..5.
   Suturiform articulation feebly curved forward medially where it is weakly crenulate.....................*C. innotata* Turner.
   C. elongatula Brues.
5. Malar space as long as the width of the eye; mesonotum entirely pale.................................*C. rotundula* Brues.
   Malar space half as long as the width of the eye; mesonotum with a black area on each lobe.............*C. natalensis* sp. nov.

Chelonogastra elongatula Brues.

Ann. South African Mus., vol. 19, p. 74 (1924).

Bulawayo, Rhodesia, August 20, 1918. Forwarded by the Imperial Bureau of Entomology.

Chelonogastra natalensis sp. nov.

Length 4 mm. Pale fulvous yellow; second and third abdominal segments obscurely brown toward the sides; antennæ, large frontal triangle including the ocelli, occiput, middle lobe of mesonotum, except behind, and the lateral lobes, except at the sides, black; tips of mandibles and tarsal claws piceous. Wings moderately infuscated. Ocelli in an equilateral triangle, twice as far from one another as from the eye-margin; eyes large; faintly emarginate next to the antennæ, one-half longer than wide; malar space grooved, half as long as the width of the eye. Head above smooth and polished; face shining, faintly shagreened. Joints of antennal flagellum gradually decreasing in length, the first one-half longer than thick. Mesonotum smooth, polished, notauli deep, not crenulated. Scutellum smooth, with a straight, foveate groove at base. Propodeum and all pleuræ smooth, no mesopleural furrow. Abdomen coarsely rugose reticulate on the second and third segments; fourth and fifth much more finely sculptured, shagreened and not shining. Second segment without a median raised line, its lateral grooves distinct, broad, extending straight back from the anterior angles but not reaching the apex; suturiform articulation very strongly bowed forward medially, weakly crenulate. Median incision of fifth segment deep, the sides broadly rounded. Ovipositor stout, curved, as long as the hind tibia. Radius arising before the middle of the stigma, not reaching the wing tip, first section half as long as the first intercubitus, second section more than three times as long as the first, third as long as the other two; cubitus straight at base, arising at the upper fourth of the basal vein; second cubital cell not widened apically; recurrent nervure almost interstitial; nervulus faintly postfurcal.

Type from Weenen, Natal, December, 1923 (P. Thomasset), forwarded by the Imperial Bureau of Entomology.

Among the African species this comes nearest to *C. rotundula* Brues from which it differs conspicuously in the length of the malar space. From Szépligeti's *C. secunda* described from Spanish Guinea it differs in color, but as the describer has omitted almost all structural char-

acters in his brief description his species must remain somewhat in doubt and I have been unable to insert it in the key given above.

Ectemnoplax Enderlein is undoubtedly a synonym of Chelonogastra. I have been unable to recognize his African species, but the type of the genus, *Ectemnoplax peruliventris,* I have seen from Formosa where it is a common species.

Glyptomorpha Holmgren.

Eugenies Resa, Ins., vol. 2, p. 427 (1868).

Glyptomorpha maculata Szépligeti.

Kilimandjaro-Meru Exped., vol. 2, p. 25 (1910).

A male from Lubumbashi, Katunga, Belgian Congo from Dr. Jos. Bequaert. It is darker than the type, with the head above and the sixth segment black.

Pseudodoryctes Szépligeti.

Pseudodoryctes fenestratus sp. nov.

♀. Length 8 mm.; ovipositor 5 mm. Head fulvous; thorax, abdomen and legs bright ferruginous, anterior legs lighter and the hind tibiæ and tarsi black; antennæ and stemmaticum black; wings black, with a large oval hyaline spot extending from the second intercubitus halfway to the wing tip narrowly separated from the costa and more widely from the hind margin of the wing; stigma black, obscurely yellowish at the base. Head barely wider than long when seen from above; occiput rather acutely but not deeply excised, with a marginal carina that extends over the temples but fades out on the cheeks below. Front polished, with a broad, very shallow impression just above the antennæ; ocelli very close together. Eye circular, about half as long as the width of the temple; malar space without furrow, half as long as the eye. Head behind eyes smooth and polished; face rugose; maxillary palpi as long as the head-height. Antennal scape with the apex below prolonged into an acute tooth; flagellum very slender, densely covered with very short hairs; the basal joints five or six times as long as thick. Pronotum smooth or minutely punctulate, the anterior margin sharply elevated and set off by a transverse furrow. Mesonotum smooth and polished, one-third broader than long, notauli deeply impressed as a sharp line, meeting in a curve behind at the middle, just anterior to the tegulæ; median lobe very

strongly raised and with a faintly indicated broad impression medially in front. Propodeum smooth and polished, feebly convex in profile, with several very much abbreviated longitudinal carinæ at apex, the longest of these extending as far as the spiracle. Pleuræ smooth and polished; mesopleural furrow deeply impressed, linear. Legs rather slender for this group although the femora are distinctly thickened, the hind femur one-fourth as broad as long; hind coxa smooth, shining, twice as wide as long; front tarsus not quite one and one-half times as long as the tibia; hind tarsi barely longer than their tibiæ; hind metatarsus not quite so long as the following tarsal joints together. Petiole of abdomen longer than wide, the tip one-half wider than the base, its surface punctate-striate, with a pair of carinæ that converge slightly and do not reach the middle of the segment. Median area of second segment smooth, except for a cross-striated transverse furrow at the middle, two-thirds as wide as the segment, arcuately rounded behind where it is bounded by a striated furrow that forks at the sides leaving a shining tubercle that lies behind and inward of the rugose, separated anterior corners. Following segments smooth. Radial cell reaching the wing tip; first section of radius one-third as long as the second which is half as long as the third; first section of cubitus gently sinuate; second cubital cell slightly narrower at tip which is half as long as the upper edge; nervulus postfurcal by its own length and entering the discoidal cell at the basal fifth; cubitus suddenly becoming hyaline at the basal fourth of its last section; third discoidal cell closed at apex; nervellus arising at the lower fourth of the cell. Submediellan cell in hind wing very short, minute.

Type from Uganda; Entebbe, August, 1912, (C. C. Gowdey).

Structurally this species seems to be very similar to *P. camerunus* Szép. (Ann. Soc. Ent. Belgique, vol. 58, p. 115, 1914), but differs in the shorter ovipositor and entirely different coloration of the wings.

Odontobracon Cameron.

Biol. Centr. Amer., Hymen., vol. 1, p. 384 (1887).

Odontobracon ? spilopterus Cameron.

Zeits. f. Naturwiss., vol. 81, p. 442 (1909) (*Zombrus*).
Brues, Ann. South African Mus., vol. 19, p. 141 (1924).

There are two females of this beautiful species from Durban, Natal (Feb. 2, 1913) (A. L. Bevis) and April 1, 1917 (C. N. Barker).

In this species the body is much longer and more slender than in other members of the genus and the large median area on the second abdominal segment is obliquely widened behind to the posterior corners of the segment, the grooves which limit it diverging and not curving medially behind. Whether this character is sufficient to place *O. spilopterus* in a distinct genus, I cannot say. The coloration of the wings is unusual also, but is essentially similar in *O. maculifrons* Cam. This latter species I have never seen and do not know whether it is similar structurally.

Odontobracon flaviceps Cameron.

Ann. Entom. Soc. Belgique, vol. 56, p. 373 (1912).

There is a female from the Tero Forest, Uganda (C. C. Gowdey) sent by the Imperial Bureau of Entomology that seems to be this species although only about half the size of the type, 13 mm. The ovipositor is nearly as long as the body.

SUBFAMILY RHOGADINÆ.

Phænodus Förster.

Verh. naturh. Ver. preuss Rheinlande, vol. 19, p. 241 (1862).
MARSHALL, Hymén. Europe et Algérie, vol. 5 bis, p. 95 (1897).
SZÉPLIGETI, Genera Insect., fasc. 22, p. 78 (1904).
SCHMIEDEKNECHT, Hymen. Mitteleuropas, p. 514 (1907).
ENDERLEIN, Arch. Naturg., Jahrg. 84A (1918) Heft 11, p. 145 (1920).

This genus was for many years represented by a single species from Europe, *P. pallipes* Marshall, but recently Enderlein has described a second one from Brazil. In the present material there is a third form from Rhodesia. It appears therefore that Phænodus enjoys a distribution much like that of Helorimorpha, except that it has so far not been discovered in North America.

Phænodus africanus sp. nov.

♀. Length 2.5 mm.; ovipositor as long as the first abdominal segment. Black, palpi and base of mandibles whitish; legs pale yellow; tegulæ testaceous, antennæ yellow at base, darker from the eighth joint to the 17th (tips broken); wings hyaline, stigma and veins pale yellowish. Head shagreened above, the posterior marginal line very strong, somewhat angulate medially above. Head, seen from above, very broad, the temples very short and rapidly narrowed; occiput

strongly concave medially; head much narrowed below the eyes which are oval, scarcely longer than the malar space; face indistinctly transversely wrinkled; margin of clypeus nearly straight below, the mouth opening strongly tranvserse; head below the eyes and behind smooth and polished. Antennæ with the scape very short, oval; pedicel nearly as thick as the scape, rounded; first flagellar joint as long as the scape and pedicel together, fully four times as long as thick; second and each following a little shorter (tips broken off at 17th joint). Pronotum unusually long, carinate in front, with a coarsely crenate furrow behind; in the middle with a transverse opaque band. Mesonotum highly convex, in profile the posterior part sets at right angles with the anterior portion; its surface smooth and shining; notauli very distinct and sharply impressed, almost meeting behind. Scutellum long and narrow; basal groove very broad, with a large fovea at each side and a series of approximate striæ nearer the median line. Propodeum with a long median area defined by stout carinæ; sharply, more or less transversely reticulate; lateral thorns conspicuous, directed slightly upwards and outwards, about as long as the antennal scape. Propleura coarsely, irregularly wrinkled; mesopleura with a crenulate furrow below, convex and smooth medially, above in front coarsely reticulate, behind with a crenate line. Abdomen oval. First segment closely and finely striate, the sides nearly smooth; base half as wide as apex which is equal to the length. Second segment large, smooth and polished, occupying all but the apex of the abdomen where a very short third and fourth segment are visible. Sheaths of ovipositor with a few loose silvery hairs like those that clothe the head and thorax. Legs moderately slender; tibial spurs extremely small. Stigma long and narrow; radius arising at the middle; radial cell long, but not quite attaining the wing tip; second section of radius nearly twice as long as the first; third three times as long as the second; cubitus arising near upper end of basal vein; recurrent nervure interstitial; second transverse cubitus nearly hyaline, perpendicular to the cubitus and radius; first transverse cubitus very strongly oblique, the second cubital cell greatly narrowed above; nervulus postfurcal; nervellus interstitial. Hind wing with the submediellan cell one-fourth as long as the mediellan; transverse discoidellan vein present, interstitial with the basellan vein.

Type from Rhodesia; Bulawayo (C. E. Pead).

This differs from the European *P. pallipes* in having the antennæ dark at least to the 17th joint. In the type and apparently only known specimen of *pallipes* they are white from the 13th joint, but

Marshall states that the antennæ are broken beyond the 18th joint. The antennæ of the South American species are also white apically. It is difficult to make structural comparisons as Marshall's type was very poorly preserved, but it appears that the abdominal petiole of the present form is much broader, the anal vein more distinct and certainly the venation of the hind wing is very distinct, not "sans nervures."

The genus Bæocentrum (*Brachycentrus*) described by Szépligeti, I do not know in nature, but may be related to Phænodus as it bears tubercles on the propodeum. The abdominal structure is in no way similar, however, since the second segment in Bæocentrum is "transverse, the third as long as the second."

Rhogas Nees.

Nov. Act. Acad. Nat. Curios., vol. 9, p. 306 (1818).

Rhogas saturatus sp. nov.

♀. Length 9 mm. Rufous; antennæ, palpi and abdomen, except basal two-thirds of first segment, black; middle legs rufo-piceous beyond the base of the femora; hind legs darker, almost black beyond the trochanters. Wings hyaline, the stigma and veins dilute piceous. Head twice as wide as thick, deeply emarginate behind with the temples arcuately narrowed; ocelli large, approximate, separated from the eye by less than twice their diameter. Eye twice as long as broad, weakly, but distinctly emarginate; malar space two-fifths the eye-height. Antennæ considerably longer than the body; first flagellar joint over twice as long as broad; second and following shorter, but all are longer than wide. Vertex very closely punctate; front irregularly, more or less transversely striate; face and head behind the eyes more finely punctate than the vertex; malar space vertically rugose. Head strongly and completely margined behind. Pronotum with the lateral foveæ widely separated, surface finely rugulose. Mesonotum without distinct median lobe, parapsidal furrows faintly indicated behind; surface finely rugose. Basal groove of scutellum finely striated, the metanotum more coarsely so; propodeum rather coarsely rugose medially, finely so on the sides; upper angles not indicated; with a prominent median carina at the base which does not extend beyond the middle. First segment of abdomen less than twice as long as wide, apex one-half wider than the base, coarsely rugose, with a prominent median carina that extends over the second segment, but

not beyond; second segment three-fourths as long as the first, slightly wider than long, rather coarsely longitudinally rugose; third segment two-thirds as long as the second, more than twice as broad as long; finely longitudinally rugose at base, punctulate on apical third; fourth segment half as long as the third; following concealed. The first suture is deep and simple; the second more shallow and crenulated. Pleuræ rugulose, more finely so below. Spurs of posterior tibiæ almost straight, pubescent, the longer one-half the length of the metatarsus; tarsal claws simple, not toothed before apex. Stigma three times as long as wide; radius arising at middle; first section three-fifths as long as the second; third longer than the other two together; first and second transverse cubital veins equal, the second cubital cell slightly narrowed above, the upper edge about one-fifth longer than the base; recurrent nervure received half its length before the tip of the first cubital cell; submedian cell longer than the median by one and one-half times the length of the nervulus. Radial cell of hind wing evenly expanded apically, without trace of cross-vein; sub-median cell two-thirds as long as the median.

Type from Durban, Natal, January 13, 1917 (A. L. Bevis).

This species resembles *R. ruspolii* Mantero (Ann. Mus. Civ. Stor. Nat. Genoa, (3) vol. 1, 1905) in color and general characters, but the clypeus is not carinate and the front is not sulcate. It is also similar to *R. semirufus* Szép. (Wiss. Ergebn. Deut. Zentral-Afrika Exped. 1907–08, vol. 3, p. 411) but the mesopleura is not shining above, the propodeum is carinate and the abdomen not distinctly striate.

Rhogas insignis sp. nov.

Length 7 mm. Head, including antennæ and palpi, pro and meso-thorax, including scutellum, deep black; wings very dark fuscous, nearly black; propodeum and abdomen pale fulvous; middle and hind legs, including coxæ, fulvous, the second joint of trochanters, tips of femora and entire tibiæ and tarsi black. Head nearly twice as wide as thick; ocelli close together, separated by less than their own length, the posterior ones twice their length from the eye. Eyes twice as long as wide, emarginate internally. Front smooth, faintly shagreened; vertex shagreened and sub-opaque; face transversely rugose at the sides; cheeks and temples shining. Malar space almost as long as the width of the eye, without furrow. First flagellar joint fully twice as long as thick, second and following imperceptibly shorter; palpi slender. Mesonotum sub-shining, shagreened; notauli deeply impressed, crenate, the area where they meet behind coarsely rugose reticulate. Scutellum

shagreened, its basal groove sexfoveate. Propodeum very coarsely but shallowly reticulate, with complete median and spiracular carinæ. Propleura irregularly wrinkled; mesopleura rugose above, smooth and shining at middle and very distinctly but sparsely punctate below. Abdomen longitudinally wrinkled on the basal two segments which bear a longitudinal carina; the wrinkles very irregular and well separated and much weaker at the sides of the abdomen; third segment more faintly wrinkled, smooth behind and at the sides. First segment no longer than wide, a little longer than the second which is one-half wider than long and slightly widened behind; third shorter and wider; following very much narrowed. Ovipositor very short, its valves broad, oval, delicately pilose. Longer spur of hind tibia less than one-half as long as the first tarsal joint; tarsal claws pectinate, with a number of long teeth before apex. First section of radius two-fifths as long as the second which is slightly longer than the first intercubitus; second cubital cell slightly narrowed toward apex; distinctly shorter above than below; recurrent nervure entering the first cubital cell before the apex, parallel with the first intercubitus; first section of cubitus straight. Nervulus postfurcal by more than its own length. Radial cell in hind wing much widened apically, especially beyond the middle; submediellan cell half as long as the mediellan; transverse discoidal vein distinct, interstitial with the basal vein. Body and legs pale pubescent.

Type from Uganda; Kampala, November 17, 1915. The cocoon which is mounted with the specimen is pale brownish in color.

Rhogas maculicornis sp. nov.

♂. Length 5.5 mm. Bright fulvous, the head paler yellow; antennæ black, joints 24–29 yellowish white; last tarsal joint black; wings strongly infuscated, especially at base, stigma and veins black. Head nearly twice as broad as thick, the temples obliquely narrowed, occiput not excavated; vertex shining, faintly punctulate; front transversely excavated, obsoletely aciculate transversely; ocelli small, very closely approximate. Eyes elongate, twice as long as broad, broadly emarginate next to the antennæ; face opaque above, minutely rugulose, more shining and punctulate below; cheeks and head behind smooth and shining; malar space half as long as the width of the eye. Antennæ slender, the basal joints of flagellum about equal, twice as long as thick. Mesonotum moderately convex, the notauli complete, but not deeply impressed; surface finely rugose, subopaque; groove at base of scutellum strongly arcuate, with six cross-carinæ. Propodeum

very finely reticulate, with a faint median carinate line. First three segments of abdomen finely striate-reticulate, the apex of the third smooth; first and second with a very faint raised median line; first segment as long as broad at apex, the apical margin feebly emarginate on each side; second segment as long as the first, widened behind; third two-thirds as long and wider than the second; fourth to sixth short, shining, bent downwards. Ovipositor very short, scarcely projecting. Propleura irregularly striate reticulate; mesopleura shining, faintly punctate except above where it is opaque and longitudinally aciculate; sides of propodeum shagreened, subopaque. Longer spur of hind tibia attaining the middle of the metatarsus, tarsal claws with two long comb-like teeth before apex. Radial cell not attaining the tip of the wing; first section of radial vein half as long as the second; second cubital cell slightly narrowed apically and above, the first intercubitus about as long as the second section of the radius; nervulus widely postfurcal, entering the middle of the first discoidal cell; recurrent nervure received more than half its length before the tip of the first cubital cell. Submediellan cell in hind wing half as long as the mediellan; radiellan cell much widened apically, not contracted at the middle. Body rather stout, clothed with fulvous hair that is quite conspicuous on the abdomen and legs.

Type from Uganda; Entebbe.

This species resembles *R. annulicornis* Szépligeti from Madagascar, in the ringed antennæ, but that is a black species.

Rhogas ecuadoriensis nom. nov.

Recently Enderlein has used the name *annulicornis* for a neotropical species (Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 155 (1920). As this is antedated by Szépligeti's species, I propose the name *Rhogas ecuadoriensis* nom. nov. for *R. annulicornis* Enderlein, *nec* Szépligeti.

Rhogas bevisi sp. nov.

♀. Length 5 mm. A pale, slender species, with the abdomen coarsely striated to the tip of the third segment. Entirely pale luteous, the space between the ocelli black; antennæ slightly darker than the body. Head distinctly less than twice as wide as thick, the occiput straight, not emarginate; occipital carina very strong, temples sharply narrowed, not convex in dorsal view. Ocelli separated by less than their width, from the eye margin by three times their length.

Eyes oval, not emarginate; malar space three-fourths as long as the eye; palpi very slender; surface of head finely shagreened. Antennæ very slender, first flagellar joint but little longer than the second, about four times as long as thick; joints near middle of flagellum each three times as long as thick. Pronotum without distinct lateral foveæ. Mesonotum long, the median lobe distinctly raised, but not prominent; notauli weakly impressed for their entire length. Metanotum with six foveæ, separated by carinate lines; surface of mesonotum opaque, rugulose. Propodeum gently sloping, very irregularly longitudinally reticulate; posterior angles not indicated; median carina complete. First segment of abdomen one-half longer than wide, the base little more than twice as broad as the apex; with about 18 quite regular longitudinal striæ, each nearly as prominent as the median carina; second segment scarcely widened behind, one-third longer than broad; striate like the first; with the striæ slightly more widely separated; third segment broader than long, three-fourths as long as the first, its basal articulation crenulated by the striæ which are continuous with those of the second segment; the striæ extend to the posterior margin where they number about 24; fourth segment faintly striate at the base, smooth beyond; half as long as the second. Pleuræ finely granulate, the propleura with some very coarse horizontal and oblique striæ above. Legs very slender; spurs of hind tibiæ slightly curved, faintly pubescent, very short, extending only to the basal fourth of the metatarsus. Wings rather narrow; hyaline, the venation and stigma pale brown; nervulus entering discoidal cell at its basal third; recurrent nervure entering the first cubital cell as far from its tip as the length of the first transverse cubitus; stigma three times as long as broad, emitting the radius at its middle; first section of radius equal to the second, the two together half as long as the third, second cubital cell narrowed above and apically, its basal side distinctly shorter than the upper and one-half longer than the outer; nervellus arising almost at the lower corner of the third discoidal cell which is three times as long as high. Radial cell in hind wing gradually widened apically and weakly constricted at the middle; submedian cell three-fifths as long as the median.

Type from Umbilo, Durban, Natal, October 25, 1924 (A. L. Bevis).

This species resembles the South African *R. varitinctus* in general form and sculpture, but differs at once in the small, trapezoidal second cubital cell, and in the much shorter spurs which are not or at most very slightly longer than the width of the tibia at its tip.

Possibly the present species should be referred to Heterogamus,

typical species of which it approaches in the short spurs and lengthened first section of radius, but at best these two genera must be regarded as very difficult to separate.

Rhogas nigrinervis Szép.

Kilimandjaro–Meru. Exped., vol. 2, p. 37 (1910).

One example from Kabete, Nairobi, British East Africa (T. J. Anderson), forwarded by the Imperial Bureau of Entomology. Somewhat darker than the type and strongly blackened on the sides of the thorax and lateral margins of the abdomen. A second one from Natal; Weenen, 2840 ft., January (H. P. Thomasset) is much lighter.

As these smaller species are difficult to separate without reference to their less conspicuous characters, I have appended a description which will supplement the one given by Szépligeti.

Testaceous, with darker markings. Ocellar area, spot on head behind eye and stripe along pleuræ blackish; pleural stripe wider and darker on the mesopleura of which it occupies the upper half; apical third of middle and apical half of hind tibiæ black; antennæ infuscated apically. In darker specimens the head is mostly black, the pleuræ entirely dark and the sides of the abdomen blackish. Wings slightly yellowish; stigma pale testaceous; veins light brown. Head one-half wider than thick, obliquely narrowed behind the eyes, the occipital carina strong. Ocelli large, well separated, the posterior ones nearly as far from one another as from the eye-margin. Vertex shagreened and minutely reticulate, front coarsely transversely striate below the ocelli, with some more or less vertical carinæ in the antennal basin. Eyes broadly and rather deeply emarginate; large, oval, more than twice as long as the malar space. Face minutely rugose below and at the sides, transversely rugose-striate medially and above. Antennæ with all the flagellar joints about twice as long as thick; second joint of maxillary palpi quite distinctly swollen, more than one-third as thick as long. Thorax long and slender; mesonotum finely rugose, considerably longer than wide; notauli not impressed, feebly indicated anteriorly. Abdominal striation coarse, extending nearly to the tip of the third segment, the second suture strongly crenulate. First section of radius two-thirds as long as the second; second cubital cell scarcely narrowed apically, one-half longer than high; recurrent nervure received two-thirds its length before the apex of the first cubital cell; first section of cubitus sinuous; nervulus postfurcal by

twice its length; submediellan cell of hind wing more than half as long as the mediellan; radiellan cell but little widened toward apex.

Rhogas varinervis Cameron.

Ann. Transvaal Mus., vol. 2, p. 198 (1911).

One specimen from Umbilo, Durban, Natal (A. L. Bevis). In this species the tarsal claws are simple as seems to be the case generally in the slender forms.

Cordylorhogas Enderlein.

Arch. Naturg., Jahrg 84A (1918), Heft 11, p. 153 (1920).

Cordylorhogas africanus Brues.

Ann. South African Mus., vol. 19, p. 82 (1924) (*Gyroneuron*).

This species is referable to Enderlein's genus, the description of which unfortunately did not reach me till my previous paper had gone to press. In color it resembles the type, *Cordylorhogas trifasciatus* Enderlein almost exactly. It may be distinguished by the sculpture of the propodeum which lacks a transverse carina and has the lateral angles carinate. Also the pleuræ are nowhere striate and the thickening of the wing reins is not the same. I refer it to the genus on the basis of the peculiarly angulate carina behind the ocelli.

Hemigryoneuron Baker.

Philippine Journ. Sci., vol. 12D, p. 322 (1917).

Hemigyroneuron apicale sp. nov.

♀. Length 10 mm. Pale fulvous, the palpi more nearly testaceous; antennæ, ocellar spot and last joint of hind tarsi black; apical joints of four anterior tarsi and ovipositor fuscous; apex of abdomen slightly darker than the rest of the body. Wings hyaline at base, their apices from the base of the radial cell noticeably infuscated; stigma and veins bright fulvous, the latter but slightly darker on the infuscated part of the wings. Head fully three times as broad as thick, the occiput broadly emarginate; temples very short with the head greatly narrowed behind the eyes; occipital carina obsolete medially. Eyes very large, strongly emarginate, fully eight times as long as the malar space; ocelli very large, separated by less than their

own diameter, the lateral ones contiguous to the eye; front smooth and shining; face finely transversely rugose, slightly higher than wide, including the clypeus. Antennæ as long as the body, tapering; basal joints of flagellum quadrate, apical ones longer than thick. Mesonotum subopaque, finely confluently punctate and like the rest of the body and appendages, quite densely clothed with short, dense, glistening fulvous hairs; parapsidal furrows faintly impressed anteriorly, obsolete behind. Scutellum sexfoveate at base, in addition to a larger lateral fovea; postscutellum also sexfoveate. Propodeum only moderately convex above, its dorsal surface gradually sloping behind; upper angles not indicated; spiracle oval, subspiracular carina very short; surface finely reticulate, without median areas or carinæ. Prothorax irregularly reticulated, the pleura with the posterior impressions transversely striated for their entire length; mesopleura shining, faintly punctate, above with some irregular vertical striæ; metapleura more or less finely transversely striate. Abdomen about as long as the head and thorax, with seven visible segments; the first two irregularly longitudinally aciculate and with strong median carina; third faintly aciculate at base, becoming obsoletely punctate and finally smooth apically; following smooth; first segment twice as wide at apex as at base and slightly longer than wide; second slightly transverse and shorter than the first, slightly widened behind; third clearly shorter than the second and wider than either the second or fourth, nearly twice as wide as long; fourth about half as long as the third but scarcely narrower; fifth, sixth and seventh narrowed and bent downwards. Radial cell almost attaining the tip of the wing; stigma narrow, emitting the radius just before the middle; first section of radius two-thirds as long as the second, third distinctly longer than the other two together; second cubital cell scarcely narrowed apically, outer edge two-thirds as long as the upper; recurrent nervure entering the first cubital cell, separated from the first intercubitus by more than half its length; median vein thickened, especially beyond the basal vein, curved apically; nervulus curved, much swollen at the middle, entering the first discoidal cell slightly beyond the middle; submedian cell almost devoid of trichiation, with two chitinous flecks (like those of Enicospilus) in the center below the basal vein; radiellan cell of hind wing greatly widened apically, the submediellan half as long as the mediellan. Legs rather stout, spurs of hind tibiæ nearly equal, pubescent below and faintly curved, the longer one-half the length of the first tarsal joint.

Type from Durban, Natal, December 4 (C. N. Barker).

This species agrees well with Baker's diagnosis of Hemigyroneuron (Philippine Journ. Sci., vol. 12D, p. 322, 1917) except for the longer first section of the radial vein. It is the second member of this group of genera to be described from Africa. The first, Cordylorhogas, at least as represented by *C. africanus* Brues from Zululand, differs by the smaller eyes and ocelli as well as in venation, particularly the thickened veins. The tarsal claws are pectinate in both forms. Enderlein does not mention the latter in his diagnosis of Cordylorhogas, but presumably his type species does not differ in this respect.

Subfamily OPIINÆ.

Rhinoplus Förster.

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 258 (1862).

Rhinoplus fuscipennis Szépligeti.

Mitt. Zool. Mus. Berlin, vol. 7, p. 226 (1914).

One female, Belgian Congo; Walikale, January (J. Bequaert).

This agrees perfectly with Szépligeti's description. The head is very broad behind, if anything slightly wider behind the eyes which are very small, no longer than the malar space. The head is margined behind on its lower half. This is apparently the first species of Förster's genus Rhinoplus and will have to stand as the type. The medially produced clypeus is characteristic of several genera of Diospilinæ and as the posterior margin of the head used to separate the subfamilies Diospilinæ and Opiinæ is subject to variation there is reasonable doubt concerning the proper location of the present genus. The species will, however, run to Rhinoplus in any of the published keys.

There is a male in the present collection which undoubtedly represents a second species very similar to the foregoing. Unfortunately the male of *R. fuscipennis* is unknown but the differences can hardly be of a sexual nature. The following key will suffice to distinguish the two.

Head, thorax above and propleuræ black; eye larger, separated by its own width from the posterior margin of the head when seen in lateral view; face sparsely punctate......... *R. fuscipennis* Szépligeti.

Entire body fulvous; eye smaller, removed from the posterior margin of the head by much more than its own width; face confluently punctate above............. . ...*R. fulvus* sp. nov.

Rhinoplus fulvus sp. nov.

♂. Length 6 mm. Fulvous, somewhat darker along the bases of the abdominal tergites; antennæ and last joint of tarsi black; wings dark fuscous, stigma and veins black. Head much less than twice as broad as thick. Head slightly widened behind the eyes, the temples sharply rounded and the occiput strongly emarginate. Head smooth and polished above and behind; marginal carina distinct below the middle, the temples and occiput immargined; ocelli small, very close together, occupying a small prominence that sets in a transverse impression on the vertex. Face with a median elevation or ridge; its surface punctate, sparsely below and confluently above; clypeus produced triangularly to a small point medially; eye about as long as the unfurrowed malar space; mandible with two broad teeth at apex. Antennæ slender, first three joints of flagellum subequal, fully twice as long as thick, those near the middle less than twice as long as wide. Middle lobe of mesonotum strongly elevated anteriorly, with a median furrow which becomes very deep and broad behind; notauli smooth, deeply impressed in front, but disappearing at the middle before reaching the median furrow. Mesonotum and scutellum shining, with a few faint scattered punctures; scutellar groove divided by a single median ridge. Propodeum irregularly, quite coarsely reticulate. Pro- and mesopleuræ smooth and polished; mesopleural furrow finely crenulate. Abdominal petiole as long as wide at tip, spiracles strongly tuberculate; from each anterior angle there arises a carinate ridge, these converge then separate and disappear before the apex; sides smooth, concave; middle section incompletely longitudinally striated. Sutures beyond second segment indistinct. Hind tibial spur one-third the length of the metatarsus; tarsal claws very large and strong, with a broad tooth at the base. Second section of radius almost three times as long as the first; third nearly three times as long as the second. Basal vein slightly thickened, cubitus arising at its upper fourth, the first section of cubitus sinuous; recurrent nervure and first intercubitus of equal length, interstitial and forming a straight line; upper side of second cubital cell as long as the basal one and more than twice as long as the apical side; nervulus vertical, postfurcal by about its own length; nervellus arising below the middle of the cell. Radial cell in hind wing gradually narrowed to tip; submedian cell half as long as the median; postnervellus complete, arising just beyond the basal vein and extending to the hind margin of the wing.

Type from Uganda; Tero Forest, July, 1912 (C. C. Gowdey).

As mentioned above this is very similar to *R. fuscipennis* known

only from the female; however, the eyes are smaller, not larger as one might expect in the male aside from the other differences enumerated.

Opius Wesmael.

Mém. Acad. Sci., Bruxelles vol. 9, p. 115 (1835).

Opius vittator sp. nov.

♀. Length 2.4 mm. Black varied with fulvo-ferruginous as follows: head, except ocellar spot and tips of mandibles; legs, except tips of tarsi; prothorax; tegulæ; mesothorax except large semicircular spot on lateral lobe and anterior two-thirds of middle lobe; scutellum and metathorax. Entire propodeum, the mesopleura and metapleura black. Wings hyaline, stigma and venation black, except near the base of the wings where all veins except the costa are testaceous. Head shining, more than twice as wide as thick, scarcely excavated behind; face with a median ridge below the antennæ; eyes twice as long as broad, their inner margins slightly convergent below; malar space one-fourth as long as the eye, with a foveate groove. Antennæ with 31–32 joints; second joint of flagellum slightly longer than the first; following growing shorter till the ones near apex are barely twice as long as thick. Mesonotum and scutellum smooth and polished; scutellar groove with eight foveæ. Propodeum very irregularly reticulate, with only a trace of a median carina visible near its base; at each side near the posterior margin with several foveate impressions. First segment of abdomen but little longer than wide, the base two-thirds as wide as the apex; on each side with a carina extending back from the basal corner and curving inwards to enclose a smooth oval concave space, behind this the surface is rugose reticulate, much more finely so at the sides; following segments smooth and shining, with the sutures smooth but clearly impressed. Ovipositor as long as the abdomen. Width of stigma twice the length of the first section of radius; second section three times the first; third slightly exceeding the other two; nervulus postfurcal by distinctly more than its own length; recurrent nervure entering the second cubital cell; second intercubitus not distinctly more than half as long as the first, which is two-thirds as long as the second section of the radius; nervellus arising near the lower angle of the lower discoidal cell.

Type and paratype from Umbilo, Durban, Natal, October 10, 1919 (A. L. Bevis).

This species appears certainly to be undescribed in spite of the great

activity in unearthing species of the genus in Africa. From most of these it may be distinguished by the insertion of the recurrent nervure well beyond the base of the second cubital cell. From *O. africanus* Szép. it differs by the long ovipositor; from *O. inconsuetus* Silv. in having many fewer joints to the antennæ; from *O. nigromaculatus* Szép. and *O. fuscitarsis* Szép. in having the mesopleural groove very strongly crenulate.

Opius bevisi sp. nov.

♀. Length 3 mm.; ovipositor 2.0 mm. Bright fulvous, antennæ and sheaths of ovipositor black; hind tarsus and apical joint of others fuscous; body, including abdomen with sparse pale hairs. Head twice as wide as thick, broad behind the eyes; occiput deeply semicircularly excavated; cheeks and lower part of temples margined, the carina not reaching the level of the upper eye margin; eyes rounded, but little longer than wide, the malar space one-fourth the length of the eye, without furrow; ocelli very close together; vertex with a few large punctures and with some indistinct, more or less transverse rugæ; frontal basin between antennæ and ocelli strongly striate, the upper striæ strongly bowed upwards medially; face coarsely punctate with a smooth median ridge; cheeks and occiput smooth and shining. Antennæ with more than 32 joints, the tips broken in the type; second flagellar joint quite distinctly longer than the first, those beyond growing shorter, but the thirtieth still more than twice as long as thick; palpi simple, long and slender. Mesonotum smooth and shining with very deeply impressed notauli which bear anteriorly several large foveæ that extend well on to the lateral lobes; scutellar groove broad, divided by three cross carinæ; scutellum shining; metanotum with many longitudinal carinæ so that it appears to bear a transverse series of large foveæ. Propodeum at base transversely wrinkled, with a median carina; behind and at the sides coarsely reticulate. Propleura with a transversely striated oblique groove; mesopleural groove deeply impressed, crenulate; mesopleura smooth; metapleura obsoletely punctate. First segment of abdomen almost twice as long as wide, the apex one-half wider than the base, finely longitudinally striated, with a lateral carina that extends from the anterior angle straight back to the middle of the segment and a deep lateral groove which marks the outer edge of the tergite. Second and following segments smooth, the sutures between them indistinct. Abdomen as long as the head and thorax together, three times as long as wide. Stigma emitting the radius distinctly beyond the middle; first section

of radius three-fifths as long as the second which is slightly shorter than the first intercubitus, third twice as long as the other two; nervulus postfurcal by less than half its length, nervellus arising at the lower third of the cell, recurrent nervure interstitial; second cubital cell much contracted apically, the second intercubitus but half as long as the median.

Type from Doonside, Natal, January, 1917 (A. L. Bevis).

Among African species this seems to be most closely allied to *Opius* (*Hedylus*) *giffardii* Silv., but differs in having the abdomen entirely smooth beyond the petiole, the eyes more nearly circular, the second cubital cell strongly narrowed apically and the ovipositor shorter. From Silvestri's description and figure it is evident that *H. giffardii* must be referred to Opius as defined by Gahan in his revision of the North American Opiinæ (Proc. U. S. Nat. Mus., vol. 49, p. 63). *Opius luteus* Kriechbaumer from Port Natal is similar in color, but from the brief description it is evident that the wing venation is entirely different from that of the present form.

Subfamily HELCONINÆ

Aspicolpus Wesmael.

Nouv. Mém. Acad. Sci., Bruxelles, vol. 11, p. 155 (1838).

The African species may be distinguished by the following key.

1. Third antennal joint three or four times as long as thick; anal cell with one cross vein; first abdominal segment twice as long as broad.......................... .2.
   Third antennal joint twice as long as thick; anal cell with two cross veins; first abdominal segment somewhat longer than broad................................*A. riggenbachi* Szép.
2. Stigma entirely pale; first abdominal segment with two strong ridges at base; second cubital cell half as long above as below. *A. grandior* sp. nov.
   Stigma black, except at base; first abdominal segment without ridges or carinæ basally; second cubital cell more than half as long above as below................*A. pictipennis* sp. nov.

The two new species described below agree well with Aspicolpus, but on the other hand do not differ from Pseudohelcon in any striking characters. The general color pattern in both is very similar to that of *P. tessmanni* Szép. and *P. distanti* Turner, but they are specifically distinct by morphological characters.

Aspicolpus grandior sp. nov.

♀. Length 14 mm. In general color almost exactly like the following species. Fulvous, the head lighter yellowish and the abdomen more ferruginous beyond the petiole; legs concolorous with the body, the hind ones black beyond the basal third of the tibiæ; antennæ and tips of mandibles black. Wings yellowish hyaline with infuscated markings as follows: large indistinctly outlined spot in first discoidal cell next to basal vein, one in second discoidal cell below, one surrounding the basal two sections of the radius, mostly in the cubital cells, apical band including apical third of radial cell, narrowed below the cubitus and bending forward from the hind margin toward the substigmal spot which it does not reach. Stigma and veins honey yellow, fuscous next to the dark clouds. Hind wing with a faint cloud near the base of the radial cell and another below the apex. Head seen from above almost as thick as wide, the temples bulging and as broad as the eyes. Frontal excavation shallow, including the anterior ocellus; front with a distinct carina near the eye margin; head margined behind except at the center above; surface smooth and shining except on the face where it is reticulate punctate above; clypeus sparsely punctulate. Malar space very short; posterior orbits with a finely crenulate line. Antennæ with about 40 joints, those near the tip becoming suddenly extremely short and then very slender. Mesonotum shining, closely punctulate; notauli strongly crenate, the middle lobe strongly elevated. Scutellum scarcely punctate, its basal groove strongly arched, broad, composed of oblong pits. Metanotum unusually long, with a triangular area at the middle and longitudinally wrinkled at the sides. Propodeum reticulate, very coarsely so behind. Propleura coarsely reticulate, shining and punctulate above and below; mesopleura finely punctate, with a reticulate punctate groove below. Abdomen almost as long as the head and thorax, subsessile. First segment twice as long as wide at tip, the base slightly more than half as broad as the apex; surface reticulate, smooth medially on the basal declivity; at each angle there arises a short ridge, these converge on the basal third of the segment then diverge becoming weaker and reach the lateral margin as carinæ at its apical third. Following segments smooth and highly polished, slightly widening to the tip of the third; second longer than the third, these two together as long as the first and as broad as long. Ovipositor nearly as long as the body, its sheaths clothed with very short hairs. Legs long, the tibial spurs very short;

first tarsal joint on all legs about as long as the following joints together. Anal cell with one complete basal crossvein and the stump of an apical one; nervulus interstitial; first discoidal cell sessile; recurrent nervure entering the first cubital cell, nearly parallel with the first intercubitus; first section of radius fully as long as the second; second cubital cell fully twice as long below as above. Radiellan cell in hind wing swollen on the basal third, the radiellus very heavily chitinized at the base, then suddenly weak as usual; submediellan cell shorter than the mediellan by more than half the length of the basal vein.

Type from Bulawayo, Southern Rhodesia, November 28, 1921, forwarded by the Imperial Bureau of Entomology.

This species is so strikingly like the following one in color and its mottled wings that I was surprised to find it quite different structurally. It is not quite typical of the genus in the longer second cubital cell and quite distinct frontal excavation.

Aspicolpus pictipennis sp. nov.

♀. Length 9 mm.; ovipositor 6–7 mm. Pale fulvous, antennæ, interocellar area, apical half of hind tibiæ, their tarsi and sheaths of ovipositor black; abdomen sometimes darkened apically above; wings hyaline, with very faint infuscated transverse bands at basal and apical thirds; these would be hardly noticeable were it not that the veins which are elsewhere pale fulvous are here blackened; thus the apical third of costa, basal vein, nervulus, median vein before and beyond it, lower side of third discoidal cell, apical half of stigma, first section of radius, upper part of first intercubitus, second intercubitus, all but base of second section of cubitus and apical half of stigma are black. Head almost as thick as wide, the temples bulging; occiput very strongly margined, not incised above; frontal impression very shallow, the face strongly protuberant above at the insertion of the antennæ. Ocelli very large, separated by less than their length, the lateral one one and one-half times its length from the eye; anterior one just in the edge of the excavation. Clypeus with the margin gently curved; clypeal foveæ very deep. Malar space very short, no longer than the width of the antennal flagellum. Head behind smooth and shining with a few punctures behind the eyes, front and face rugulose, clypeus shining and finely punctate. Antennæ scarcely longer than the body; scape twice as long as thick; pedicel rounded; first and second flagellar joints equal, very long, each four times as long as thick, third decidedly

shorter, the following gradually becoming shorter and more slender, the apical joints about one-third longer than broad. Mesonotum sparsely finely punctate with the median lobe elevated in front, flat behind; notauli crenulate in front, confluent on the posterior half by a triangular rugose-reticulate area; basal impression of scutellum less than twice as wide as long, more or less reticulate, with a median carina; disc of scutellum small, elongate oval, convex, closely punctate. Propodeum coarsely rugose reticulate, with a short basal spiracular carina. Petiole of abdomen twice as long as wide at tip, irregularly longitudinally reticulate, with a median smooth callosity at apex from which the reticulations radiate more or less clearly; remainder of abdomen shining, smooth, the sutures barely discernible; second segment twice as wide as long; third shorter; fourth to eighth still shorter, subequal. Legs slender; hind coxæ subtriangular, one-half longer than wide at base; hind tibiæ almost twice as long as the femora, longer spur one-fourth the length of the metatarsus which is as long as the following joints together. Radius arising distinctly beyond the middle of the stigma, nearly attaining the wing tip, its second section slightly longer than the first and one-fourth the length of the third; nervulus interstitial; anal cell with a single cross-vein; the basal vein as long as the first section of the cubitus; the recurrent nervure one-fourth shorter, entering the first cubital cell near its tip; inner and lower sides of second cubital cell equal, one-half longer than the second section of radius and one-third longer than the second intercubitus which is perpendicular to the cubitus; nervellus arising at the lower corner of the cell. Sheaths of ovipositor thinly hairy.

Type from Tsumeb, Southwestern Protectorate, January 1921 (E. Kochig); paratype from Southwest Africa, 1921 (Miss Wilman). Type in the South African Museum, paratype in the writer's collection. A male, 6 mm. in length, from Hope Fountain, Southern Rhodesia, February 12, 1921 (N. Jones) is among the material sent by the Imperial Bureau of Entomology.

This species will run to Aspicolpus in the tables given by Ashmead and Szépligeti as well as in Turner's key to Australian genera and does not agree with any of the genera not included in these tables. It differs from the African *A. riggenbachi* Szép. in having only one anal cross-vein, however. It resembles the type species of Eumacrocentrus, *E. americanus* Cress. quite closely, but the frontal excavation is very poorly developed and the second cubital cell much shorter.

Phanerotoma Wesmael.

Nouv. Mém. Acad. Sci. Belgique, vol. 11, p. 165 (1838).

To the already rather extensive series of species from Africa I have to add three more which are clearly distinct from those hitherto described. To facilitate their determination the following key is included:

1. Large species, 6 mm.; nervulus entering discoidal cell at basal fifth; second intercubitus much shorter than the second section of the radius.. ... .*P. major* sp. nov.
   Smaller species, 3 mm. or less; nervulus entering discoidal cell beyond the basal third; second intercubitus longer........ 2.
2. Hind tibiæ with black and whitish markings; apical joints of antennæ moniliform, no longer than wide..*P. ornatula* sp. nov.
   Hind tibiæ entirely testaceous; apical joints of antennæ twice as long as thick...... .... *P. uniformis* sp. nov.

Phanerotoma major sp. nov. (Fig. 1, C).

♀. Length 6 mm. Fulvo-testaceous, the abdomen and anterior legs somewhat paler and more yellowish; flagellum of antennæ, stemmaticum and teeth of mandibles black; wings yellowish hyaline, stigma yellow; veins light brown, except the basal, median and base of radius and cubitus, which are yellow. Head less than twice as broad as thick; temples as broad as the eye; occiput semicircularly excavated, with a fine marginal carina. Front very shallowly rugosopunctate, the vertex with indications of transverse striation medially; front finely rugose; clypeus feebly punctate; sides of head rugose next to the eye, quite distinctly vertically striate behind; malar space one-fourth as long as the nearly circular eye; ocelli large, equidistant, separated by their own diameter. Antennæ with more than 17 joints (tips broken); scape nearly as long as the eye, four times as long as thick; first four flagellar joints very long, each two-thirds as long as the scape and four times as long as thick; following growing shorter, widest at about the tenth joint. Mesonotum more densely rugose than the head; scutellum nearly smooth, triangular, very slightly raised above the axillæ which are deeply reticulate; basal scutellar groove coarsely crenate. Metanotum half as long as the scutellum, with a series of about seven longitudinal furrows on each side. Propodeum rugose, reticulate on the posterior slope. Pleuræ reticulate punctate; the mesopleura more nearly smooth below and behind,

without furrow, but with a broad crenate groove along its posterior margin. Abdomen slightly longer than the thorax; third segment as long as the other two which are of about equal length; surface longitudinally reticulated; first segment with a pair of convergent ridges extending back from the corners halfway across the segment. Legs

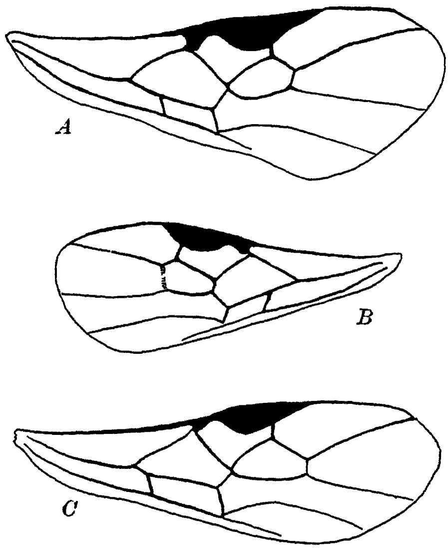

FIG. 1. Wings of Phanerotoma. A, wing of *P. ornatula*, sp. nov.; B, wing of *P. uniformis* sp. nov.; C, wing of *P. major* sp. nov.

slender; hind femora four times as long as wide. First section of radius less than half as long as the second; third two and one-half times as long as second; second intercubitus half as long as the first, recurrent nervure entering the cell less than half its length from the basal angle; nervulus arising at the basal fifth of the discoidal cell.

Type from British East Africa; Masai Reserve, May 23, 1912 (T. J. Anderson).

Phanerotoma ornatula sp. nov. (Fig. 1, A).

♀. Length 2.9 mm. Pale fulvous with testaceous legs, hind tibiæ black at base and on apical half, with a whitish annulus between; tips of antennæ blackened; ocellar area black. Wings hyaline, with a

more or less distinct infuscated band at the middle which is divided by a hyaline steak that extends across the wing from the base of the stigma; along this streak the stigma and veins are very pale, elsewhere dark, except the base of the median vein. Hind tibia whitish at the middle, with a small black spot externally at the basal third and a large one at apical third. Head less than twice as broad as thick; occiput sharply emarginate, with marginal carina. Head slightly rugose above, scarcely striated behind the ocelli which are rather small and separated by more than their own diameter; face rugulose, clypeus smooth; head behind eyes weakly rugulose, striated near the hind margin. Eyes rather large, broader than the temples, their posterior margin much less strongly curved than the anterior one; malar space one-sixth the length of the eye. Antennæ 23-jointed; scape stout, scarcely more than two times as long as thick; first four flagellar joints of about equal length, each three times as long as thick; apical joints becoming very small and moniliform. Front between the bases of the antennæ with a very distinct short median carina. Mesonotum and scutellum finely rugose; scutellar groove coarsely crenate; axillæ with about six more or less oblique carinæ. Propodeum rather coarsely reticulated, with a distinct, transverse ridge and slightly dentate post-spiracular angles. Propleuræ nearly smooth, shining; mesopleura subopaque, coarsely shagreened, without furrow, coarsely foveate on the two anterior sides and finely so on the hind margin next to the propodeum, which is much more finely sculptured on the sides than above. Abdomen a little more than twice as long as broad; first and second segments of equal length, third one-half longer than the second; surface finely rugose, longitudinally so on the first two segments; first tergite with a pair of curved convergent carinæ that extend to beyond the middle. Legs slender. First section of radius somewhat more than half as long as the second; second intercubitus much shorter than the second section of the radius; nervulus entering the discoidal cell between the middle and basal third.

Type from Natal; Weenen (thorn country), 2840 feet, January, 1924 (H. P. Thomasset).

Phanerotoma uniformis sp. nov. (Fig. 1, B).

♀. Length 2.5 mm. Yellowish fulvous, the legs paler, ocellar spot black; flagellum of antennæ infuscated from the base, becoming piceous at tip. Wings hyaline; basal half of stigma pale, apical half and veins dark, except those enclosing the median cell. Head nearly

twice as wide as long when seen from above; occiput only weakly emarginate, with a very distinct marginal carina. Upper surface of head very finely rugulose; face minutely punctulate or shagreened, clypeus smooth and shining. Eye more or less circular, with the hind edge less strongly curved, five times as long as the malar space. Temples only two-thirds as broad as the eye, minutely rugose. Ocelli separated by about their own diameter. No carina between the antennæ. Antennæ 24-jointed; scape twice as long as thick; first four flagellar joints about equal, not quite three times as long as thick, joints shorter apically but all are about twice as long as wide. Mesonotum very finely rugulose and subopaque; scutellum shagreened. Propodeum finely rugose anteriorly, reticulate behind, without distinct cross carina or post-spiracular angles. Abdomen twice as long as broad; second and third segments of equal length, first shorter; surface finely rugose, longitudinally so on basal half; carinæ at base of first segment delicate and extending only to about basal third. First section of radius about as long as the second, the second intercubitus longer than either one; nervulus entering the discoidal cell just beyond the basal third; recurrent nervure entering the second cubital cell well beyond its base. Legs stout, the hind femur nearly one-third as broad as long.

Type from Natal; Weenen (thorn country), 2840 feet, January 1924 (H. P. Thomasset). It is from the same locality as the preceding species, but is abundantly distinct in color, configuration of antennæ and in wing venation.

Sigalphus Latreille.

Hist. Nat. Crust. et Ins., vol. 3, p. 327 (1802).

Sigalphus (*Sphæropyx*) **fulvus** sp. nov.

♀. Length 6.5 mm. Bright fulvous, the antennæ, the head above except at the sides, the extreme tips of the hind tibiæ and their tarsi entirely, black; wings rather strongly infuscated, especially across the middle and at apex, the hind wing darkened except behind near the base. Head more than twice as broad as thick, deeply excavated behind; face including clypeus one-half wider than high, closely punctured and with a shallow impressed groove below the base of each antenna; clypeus shining, punctured at the sides, its foveæ deep; eyes two-thirds as broad as long, twice as long as the malar space; vertex and temple sparsely and coarsely punctate; ocelli separated

by less than their diameter; cheeks faintly punctate. Antennæ with about 30 joints, similar to those of *S. irrorator.* Mesonotum rather flat, the middle lobe with a prominent median furrow; parapsidal furrows deep but only faintly crenulated; surface as well as the scutellum sparsely punctate and shining; depression at base of scutellum deeply foveate with three cross ridges. Propodeum coarsely rugose, with a median pair of carinæ that converge basally, a transverse carina behind the middle; a lateral longitudinal carina on the basal half which slopes outward behind and attains the hind angles; upper lateral angles obsoletely toothed. Pro- and mesopleuræ shining and faintly punctulate; no mesopleural furrow; sides of propodeum with a vertical groove including a carina below the spiracle. Abdomen as long as the head and thorax together; rugose reticulate, much more coarsely so at the base; first segment distinctly separated from the gaster, slightly wider than long, but little narrowed basally; with a pair o; carinæ above along its entire length, strongly convergent behindf second segment as long as wide, but narrower basally, nearly one-half longer than the first, with a sharp carina extending from the anterior angle toward the median line and curving backwards; the two carinæ do not meet and there is no indication of a median carina; third segment as long as the second, widest at the base and almost semicircular behind, without apical teeth; suturiform articulation very feebly indicated. Legs stout, including the calcaria and tarsi; claws simple. Basal vein meeting the median almost at a right angle; nervulus only slightly postfurcal; cubitus arising at the middle of the basal vein; first section of radius one-third as long as the second which equals the third; radial cell in hind wing with a distinct cross-vein at the middle.

Type from Durban, Natal, November 18, 1917. (C. N. Barker).

This species is the second to be found in Africa, and appears to belong to this genus without much question as it is quite similar to the American *S. bicolor* Cress. although when compared with the European *S. irrorator* Fabr. there are very considerable differences, mainly in the less lengthened body and wings. From the African *S. neavei* Turner, it may be recognized by its coarsely punctate vertex and different color. The two African species are evidently quite similar.

The thorax and wings recall *Minanga serrata* Com., but the abdomen is distinctly segmented, especially between the first and second tergites.

Pachychelonus Brues.

Ann. South African Mus., vol. 19, p. 107 (1924).

This genus appears to be related to Odontosphæropyx Cameron, with which it shares the triangular clypeus and unusually thickened basal vein. It may be at once distinguished by the margined occiput, pyramidal scutellum and indistinctly segmented abdomen. The pectinate claws, anal cross-vein and thickened edge to the anal area are peculiarities not mentioned by Cameron in his description of Odontosphæropyx but as I do not know this genus cannot be sure that it possesses none of these characters.

Pachychelonus fulviventris Brues.

Ann. South African Mus., vol. 19, p. 107 (1924).

One female from Durban, Natal, March 16, 1919 (C. N. Barker).

The ovipositor extends beyond the tip of the abdomen but slightly; it is stout and blunt and densely clothed with pale pubescence near the tip.

Acanthochelonus gen. nov.

Head with the vertex transversely elevated and bearing behind each of the posterior ocelli a long slender erect spine as long as the width of the eye; eyes bare; clypeus with the anterior margin slightly rounded, subtruncate; head with a stout marginal line behind the eye, the occiput concave and immargined. Antennæ somewhat shorter than the body, tapering, first flagellar joint long. Notauli deep, convergent, but not meeting behind; scutellum small, triangular, separated by a coarsely crenate furrow; propodeum areolated by longitudinal and short transverse carinæ; mesopleural furrow present. Abdomen as long as the thorax, subglobose, broader behind; apex carinate, bilobed and denticulate; ovipositor, stout, arcuate, its sheaths paddle-shaped. Legs stout. Parastigma large, radial cell acute at apex; cubital and discoidal cells all completely separated; anal cell not divided, recurrent nervure entering the first cubital cell.

Type: *A. taurus* sp. nov.

Acanthochelonus approaches most closely to Minanga Cameron which is also Ethiopian, but differs by the long ocellar spines and nonmargined occiput. The ocelli are strongly raised in Minanga as in certain other Chelonines but there is nothing similar to the spines described above.

Acanthochelonus taurus sp. nov.

♀. Length 5 mm. Entirely bright fulvous, the antennæ black; tips of tarsi brownish. Wings pale yellowish, rather strongly infuscated apically; veins at base fulvous, beyond the parastigma dark brown. Head twice as broad as thick, the temples obliquely narrowed behind the eyes; occiput strongly arcuately excavated. Ocelli large, set in a very low triangle, separated by their own diameter, the posterior ones separated from the eye by three times their diameter; ocellar spines each arising at the inner posterior side of the ocellus, slender, erect; space between paired ocelli deeply excavated; front slightly impressed, with a carinate line leading from each lateral ocellus toward the eye. Head above smooth and polished; face and clypeus finely punctate, the face raised down the middle, with an impression extending from each antenna to the side of the clypeus. Eye oval, nearly twice as high as broad; twice as long as the indistinctly grooved malar space. Head behind the eye punctate. Palpi stout, short, with cylindrical joints. Antennal scape cylindrical, twice as long as thick; first joint of flagellum longer than the second which is twice as long as thick, joints beyond growing rapidly shorter. Notauli broad and deep, not crenulate; median lobe slightly prominent anteriorly, without median furrow; mesonotum weakly punctate; scutellum with four large foveæ at the base, its surface punctate. Propodeum very short, with a large median area extending from base to apex, basally this is divided by a short median and two transverse carinæ into four small quadrate areas; laterally with two large areas basally on each side. Propleura closely punctate above; mesopleura very finely punctate above and in front, smooth medially; with a broad impressed line below and a vertical carinate line in front; its posterior margin with a series of large foveæ; sides of propodeum coarsely longitudinally wrinkled. Abdomen entirely without sutures; with a median raised line extending to the middle; on each side with an oblique line extending from just inside the anterior corner to the median line which it joins at the basal third of the abdomen; the triangles thus formed are coarsely transversely ribbed. Outside this oblique line is another parallel with it, fading out at the middle of the abdomen before reaching the median line; surface of abdomen deeply and rather finely reticulate; tip transversely excavated, this furrow striate; posterior margin finely serrate. Tergites extending well on to the venter, especially behind. Claws simple, longer spur of hind tibia extending to the middle of the metatarsus which is as long as the three following joints together. First section of radius one-third as long as the second

which is three-fifths as long as the third; the latter arcuately bent upwards so that the radial cell is narrowed and acute at apex which is far before the wing-tip; stigma narrow, emitting the radius before the middle; basal vein very strongly oblique, thickened just above the middle where the cubitus originates; base of cubitus straight, parallel with the submedian vein; first and second intercubiti equal, the second cubital cell narrowed above, the lower side bulged outward; nervulus arising at the basal fifth of the discoidal cell; submediellan cell in hind wing more than half as long as the median.

Type and one paratype from Belgian Congo; Lubumbashi, Katanga, June 12, 1920 (Mich. Bequaert).

Subfamily MACROCENTRINÆ

Key to the Genera of Macrocentrinæ.

1. Head not margined behind; ovipositor usually longer than the abdomen; spur of hind tibia usually much less than half as long as the metatarsus .... 2.
   Head margined behind; ovipositor very short; spur of hind tibia at least half as long as the metatarsus .... 10.
2. Recurrent nervure entering the second cubital cell; middle lobe of mesonotum not prominent......... *Amicrocentrum* Schulz.
   Recurrent nervure entering the first cubital cell; middle lobe of mesonotum conspicuously elevated..................... 3.
3. Nervulus interrupted posteriorly, bifid and with two short widely divergent branches, strongly postfurcal; median and submedian veins thickened apically. *Dicranoneura* Kriechbaumer.
   Of a different conformation .... 4.
4. Longer spur of hind tibia short, decidedly less than half as long as the metatarsus .... 5.
   Spur of hind tibia half as long as the metatarsus .... 9.
5. Nervulus interstitial .... 6.
   Nervulus postfurcal .... 7.
6. First abdominal segment long and slender, as long as the two following united...... .... *Leptozele* Cameron.
   First segment much shorter and stouter, as long as the second. *Amicroplus* Förster.
7. First discoidal cell petiolate, the cubitus arising from the basal vein; radius in hind wing absent... *Amicroplidea* Ashmead.
   First discoidal cell sessile, the cubitus arising from the parastigma; radius present in hind wing...................... 8.

8. First segment of abdomen stout, two or three times as long as broad; radial cell in hind wing not noticeably constricted at the middle.. ... .*Macrocentrus* Curtis.
   First segment of abdomen very long and slender, six times as long as wide; radial cell in hind wing constricted at the middle and divided into two parts........*Aulacocentrum* Brues.
9. Palpi very long, more than twice the head-height; radial cell in hind wing weakly constricted at the middle; submedian cell with a chitinized spot near apex...........*Neozele,* gen. nov.
   Palpi of the usual length, radial cell in hind wing strongly contracted at the middle; submedian cell without chitinized spot. *Austrozele* Roman.
10. Radial cell in hind wing completely divided............. ..... 11.
    Radial cell in hind wing more or less contracted at the middle, but never divided..........................*Zele* Haliday.
11. First cubital cell very large; nervulus angled above middle. *Xiphozele* Cameron.
    First cubital cell normal; nervulus simple..*Homolobus* Förster.

Dolichozele Viereck (Proc. U. S. Nat. Mus., vol. 40, p. 182, 1911) is not sufficiently characterized for insertion in the key on the basis of the original description.

Cyclophatnus Cameron (Tijds. Entom., vol. 53, p. 54, 1910) is not placed in the key. It seems to fall near Zele, but the tibial spurs are "short." The nervulus is curved and swollen as in some Rhogadinæ.

Cænophylax Schultz is an Agathidine, possibly synonymous with Euagathis. This was described as Neophylax by Ashmead, but this name is preoccupied in the Trichoptera.

Metapleurodon, Paniscozele, Pachymerella, Apathia and Cerotopia Enderlein (Arch. Naturg., Jahrg. 84A (1918), Heft 11, pp. 213–219, 1920) are not sufficiently characterized to insert them in the key and I do not know them in nature.

Amicrocentrum Schulz

Zool. Ann., vol. 4, p. 88 (1911).

SZÉPLIGETI, Gen. Insect., fasc. 22, p. 145 (1904) *Megacentrus,* (non Heer).

CAMERON, Ann. Soc. Entom. Belgique, vol. 56, p. 370 (1912) (*Eiolo*).

A male from Juba River, Northern Frontier District, Kenya Colony collected by Dr. J. O. Beven and forwarded to me by Dr. G. A. K. Marshall seems undoubtedly to be the male of Szépligeti's *Amicro-*

centrum (*Megacentrus*) *concolor*. As the type was a female lacking legs and hind wings, Szépligeti was unable to characterize the genus completely. The legs are extremely long and slender, the longer spur of the hind tibia only about one-sixth the length of the metatarsus and the tarsal claws are bifid at the tip. The wing venation is quite extraordinary; the basal vein is straight, the first cubital cell extremely small, the third section of the radius strongly decurved and the second discoidal cell enormously widened apically, while several of the veins about the cubital cells are decolored. In the hind wing there is an oval cell containing a chitinous spot formed above the base of the cubital vein, and the radial cell is very narrow with dilated apex. The ocelli are greatly enlarged, separated from one another and from the eyes by considerably more than their own diameter. The antennæ are 41-jointed setaceous, with the apical joint tapered to a fine point. The mesonotum is evenly convex, with the notauli very weakly impressed, almost obsolete behind.

This strange creature closely resembles a good-sized Ophion or Henicospilus of rufo-ferruginous color.

Cameron's *Eiolo curvinervis* (Ann. Soc. Entom. Belgique, vol. 56, p. 372) is a synonym.

Neozele gen. nov.

Head transverse, twice as wide as thick, not margined behind, the temples rather short. Ocelli large, separated by about their own diameter from each other and the eyes; malar space short. Palpi long and stout at the base, all joints cylindrical except the second joint of the labial pair. Mandible with one preapical tooth. Mesonotum very strongly trilobed, median lobe high anteriorly. Propodeum without carinæ, spiracle oval. First abdominal segment more than twice as long as propodeum, five times as long as wide, spiracles just before the middle; second segment longer than the third, the two together as long as the first. Ovipositor very short. Apical trochanters serrate at tips outwardly; tarsal claws much thickened, with a minute hook at tip, spur of hind tibia nearly two-thirds as long as the metatarsus. Stigma long and narrow; radius issuing at the apical third; nervulus postfurcal; nervellus inserted below middle of second discoidal cell which is not enlarged apically. Radial cell in hind wing slightly constricted at the middle. Ovipositor very short.

Type: *N. wheeleri* sp. nov.

Neozele resembles Cerotopia Enderlein, but differs by the entirely immargined head, undivided radial cell in hind wing and postfurcal nervulus.

Neozele wheeleri sp. nov.

♀. Length 12 mm. Pale buff and bright fulvous with some darker markings. Head buff, with a transverse stripe including the ocelli and the tips of the mandibles black; scape above and flagellum piceous; palpi and bristly hairs above mouth fulvous. Thorax, including four anterior coxæ, buff, becoming fulvous on propodeum and hind coxæ, the lobes of the mesonotum blackened centrally. Abdomen bright fulvous, somewhat paler below. Hind legs fulvous, fore and middle ones paler. Wings hyaline, stigma fulvous, venation fuscous. Head shining, smooth above and behind; face sparsely punctate. Maxillary palpi nearly twice as long as the width of the head, the joints of nearly equal length. Mesonotum and scutellum shining, almost impunctate; base of scutellum with six foveæ. Propodeum shining, very faintly roughened with a few transverse wrinkles at the tip above. Pleuræ shining, sparsely punctate; mesopleura with a faintly impressed furrow. Abdomen shining, sparsely hairy. Stigma more than three times as long as wide; first section of radius two-thirds as long as the second which is one-third the length of the faintly decurved third section; cubitus arising from the parastigma; recurrent nervure entering the first cubital cell at its own length before the tip; apex of second cubital cell half as long as its upper side, the base one-half higher; nervulus postfurcal by more than half its length; submedian cell with an oval dark chitinous spot below near apex.

Type from Kartabo, British Guiana, July–August 1920 (W. M. Wheeler).

Although this is a neotropical form, it has been included in the present account as its affinities are indicated by the preceding key.

Austrozele Roman.

Entom. Tidskr. vol. 31, p. 113 (1910).
Brues, Psyche, vol. 29, p. 15 (1922) (*Palinzele*).

An examination of further specimens and another species from North America convinces me that Palinzele is not separable from Austrozele. The radius varies considerably, arising at the apical third or very near the middle of the stigma.

Subfamily BLACINÆ.

Blacus Nees.

Nova Acta Acad. Nat. Curios., vol. 9, p. 306 (1818).

Blacus natalensis sp. nov.

♀. Length 3 mm. Black; tegulæ, palpi and legs light yellow, the four hind tibiæ and tarsi brown. Head highly polished, smooth, with distinct posterior marginal carina; more than twice as wide as thick, the temples obliquely narrowed, broader than the eyes in dorsal view; ocelli in a small equilateral triangle less than half as far from one another as from the eye margin; front feebly excavated on each side above the antenna; eyes elongate oval, three times as long as the unfurrowed malar space; clypeus very short and broad, with deep lateral foveæ; face elevated medially. Antennæ 22-jointed, much shorter than the body; first and second flagellar joints about equal; following shorter; last ten much shorter, more or less moniliform. Mesonotum smooth and shining; notauli distinct, narrow and finely crenulated, straight and meeting some distance before the scutellum; scutellum highly convex, shining, its basal groove broad, deep, curved, divided at the middle by a raised line, its posterior depressed edge forming a curved crenate line. Propodeum faintly areolated anteriorly and at the sides; medially behind with two short longitudinal carinæ, another at the side and one on the pleural surface; above with an angled transverse carina connecting the basal ends of the longitudinal ones. Pro and mesopleuræ smooth and shining. First abdominal segment twice as long as broad at tip, base half as wide as apex; concave medially, most strongly so at the base; from each basal angle there extends backwards a sharp carina that becomes weaker behind, spiracles forming small lateral tubercles at the basal third; apical fourth longitudinally striate. Remaining segments smooth and polished, the second and third about equal, each two-thirds as long as the first; entire abdomen as long as the head and thorax and as wide as the latter. Sheaths of ovipositor smooth, almost as long as the body. Body sparsely whitish hairy on the head below, the thorax above and the propodeum; legs conspicuously clothed with glistening white hairs. Stigma two-fifths as broad as long, emitting the radius at the middle; first section of radius half as long as the width of the stigma; second curved basally, straight at apex, entering the wing-margin two-thirds of the way from the stigma to wing-tip. Cubitus arising from the parastigma; nervulus postfurcal by its own length; recurrent nervure half as long as the basal vein, parallel with it and with the intercubitus, entering the cubital cell half its own length from the tip of the latter; last section of radius and of cubitus, except at extreme base, decolored; lower discoidal cell

open at apex below; submediellan cell in hind wing half as long as the mediellan.

Type from Durban, Natal, November 7, 1919 (A. L. Bevis).

This species is the first to be described from this region. The antennæ are shorter than usual, the apical joints quite noticeably rounded and moniliform; the abdominal petiole is unusually narrow and the last section of the radius very pale in comparison with the other wing veins.

Subfamily LEIOPHRONINÆ.

Leiophron Nees.

Nova Acta Acad. Nat. Curios., vol. 9, p. 303 (1818).

Leiophron punctatus sp. nov.

♀. Length 4 mm. Entirely black, only the mandibles ferruginous; wings hyaline, the stigma piceous and veins fuscous. Head rather small, the face strongly elevated and convex below the base of the antennæ; deeply angularly excavated behind, with a marginal line below fading out on the temples; occiput smooth and polished behind the ocelli which form a large triangle with the posterior pair almost as far from one another as from the eye; vertex minutely punctate at the sides, irregularly rugose between the ocelli; temples almost as broad as the eyes, rounded and but little narrowed behind when viewed from above, but in profile it is seen that although below they are broad, above they narrow obliquely at the upper part of the eye. Eyes oval, one-half longer than wide, bare; cheeks sparsely punctulate, malar space as long as the width of the eye, without furrow. Face very convex, closely punctate, with a small elongate smooth callus just below the antennæ; clypeal foveæ extremely large and deep; the clypeus as high as broad with arcuate lower margin. Palpi stout, pale pubescent. Antennæ with more than 30 joints; scape stout, twice as long as thick; first flagellar joint the longest, three times as long as thick; following gradually becoming shorter; twenty-third and following about as long as broad and more or less moniliform. Mesonotum shining, finely sparsely punctate, longer than wide; middle lobe very convex anteriorly; notauli crenulate, meeting at the posterior third of the notum; scutellum small, highly convex, its basal groove strongly curved, crenulate. Propodeum finely reticulate, smooth and shining at the extreme base. Propleura large, rather evenly and

slightly convex above the oblique depression which is very shallow, rugose reticulate above, rugulose below; mesopleura highly polished, smooth, with a coarsely punctate, nearly horizontal furrow; metapleura convex, shining, closely but very weakly and shallowly punctate; hind coxæ shagreened and subopaque externally. Abdomen as long as the thorax. First segment the longest, one-fourth longer than wide, apex one-third wider than the base, finely punctate-reticulate at the sides and more faintly so medially except for a conspicuous polished area at the middle next the posterior margin Second segment distinctly shorter than the first, as wide as long, slightly broader behind, its surface finely, evenly confluently punctate. Third segment separated by a very distinct smooth furrow; two-thirds as long as the second, similarly punctate on the basal half, entirely smooth behind and at the extreme sides; fourth, fifth and sixth segments very short. Ovipositor directed downwards and more or less forwards, as long as the thorax and abdomen together. Legs rather stout, longer spur of hind tibia half as long as the metatarsus, the latter as long as the four remaining joints; claws simple. Stigma narrow, emitting the radius beyond the middle; first section of radius oblique, as long as the width of the stigma, nearly one-third as long as the second which is slightly and evenly curved and meets the margin halfway between the stigma and wing-tip; nervulus postfurcal by half its length; cubitus arising from the parastigma; recurrent nervure parallel with the upper part of the basal vein, entering the cubital cell three-fourths of its own length before the intercubitus; cubitus becoming obsolete not far beyond the intercubitus; nervellus near the lower angle of the second discoidal cell which is very narrowly open at the lower corner; anal cell without trace of any cross nervure.

Type from Umbilo, Durban, Natal, October 7, 1919 (A. L. Bevis).

This species seems best to be referred to Leiophron, but as there has been some difference of opinion concerning this genus, a number of generic characters have been included in the foregoing description.

Cardiochiles Nees.

Hymen. Ichneum. affin. monogr., vol. 1, p. 224 (1834).

Cardiochiles scapularis sp. nov.

♂. Length 6 mm. Black, lateral lobes of mesonotum entirely and legs fulvous beyond the base of the femora, except the apical three joints of four anterior tarsi and the posterior ones beyond the base of

the first joint, which are piceous. Wings dark fuscous, much paler on basal half; stigma fulvous; venation dark, the cubital and radial veins paler. Tibial spurs pale fulvous. Face, including clypeus, as broad as high, shining, sparsely and finely punctate; edge of clypeus broadly bidentate medially; malar space as long as the thickness of the antennal flagellum, with distinct furrow; face raised medially and depressed at each side above the clypeal foveæ; inner orbits convergent below; eyes more than twice as long as broad, coarsely pubescent; cheeks smooth, temples and antennal basin delicately punctate; vertex smooth; ocelli surrounded by a broad shallow furrow, the posterior pair nearly twice as far from one another as from the eye-margin. Antennæ with first joint of flagellum one-half longer than the second; following growing shorter, all considerably longer than wide. Mesonotum highly polished, with a very few minute punctures; notauli deep and weakly crenulate. Scutellum shining; postscutellum bifoveate. Propodeum with a lozenge-shaped superomedian area and two large lateral areas, the anterior one open basally; spiracular area elongate-triangular, its apex forming the dentate lateral angle of the propodeum; space between carinæ deeply rugose-punctate. First segment of abdomen medially with a deep impression at base and broad circular elevation behind; between the latter and the raised lateral margin is a broad groove, smooth behind and longitudinally wrinkled in front; second segment much shorter than the third, smooth and polished, the suture deep and smooth. Longer spur of hind tibia two-thirds as long as the metatarsus. First section of radius greatly thickened, one-third as long as the second, third unusually weak; first intercubitus about one-fifth shorter than the second section of radius; nervulus postfurcal by fully its own length; recurrent nervure more than its length from the intercubitus; first discoidal cell nearly twice as high at base as at apex, the cubitus arising at the upper fifth of the basal vein. Submediellan cell of hind wing long, half as long as the mediellan. Propleura closely and shallowly punctate reticulate; mesopleura smooth and shining above and below.

Type from Table Mountain, Cape Town, Cape Province, February 12, 1921 (A. L. Bevis). This species exhibits a very striking coloration and as color is quite constant in this genus, especially among the dark species, is undoubtedly distinct from any of Cameron's species. From *C. latifrons* Brues it differs in color, the smooth vertex and in wing venation.

Cardiochiles striatifrons sp. nov.

♀. Length 5 mm. Fulvous, the anterior legs and head lighter; marked with black as follows; antennæ, labrum, large spot on head above not attaining the eyes on the sides, middle lobe of mesonotum except behind, lateral lobes except edges, spot on tegulæ, tip of mesosternum, ovipositor and hind tarsi. Ocellar area smooth; upper part of supra-antennal basin and space between ocelli and eyes transversely striate; face smooth, clypeus faintly punctulate, twice as wide as high, evenly arched above, obsoletely notched at middle of lower margin; face with clypeus as wide as high; malar space grooved, as long as the basal width of the mandible; head smooth behind the eyes. Antennæ very stout basally, the first joint of flagellum twice as long as thick; second noticeably shorter. Mesonotum smooth, faintly punctulate, grooves on middle lobe broad and rather shallow, those on lateral lobes distinct; notauli finely crenulate anteriorly, more coarsely so behind; scutellum with a broad quadrifoveate groove at base, the surface smooth and shining. Propodeum strongly areolated, its surface reticulated. Mesopleura shining and minutely punctulate above and behind, more distinctly punctate near the middle coxa; metapleura closely reticulated, the upper anterior triangular portion smooth and shining. First segment of abdomen with the median lobe spatulate, as wide as the lateral one which bears a fine longitudinal groove near its inner edge; middle third of segment forming an oval convex area. Longer spur of hind tibia three-fourths as long as the metatarsus. Wings lightly infuscated; stigma entirely black, venation brown; first section of radius slightly over half as long as the second and as long as the second intercubitus; first intercubitus two-thirds as long as the second section of the radius; cubitus arising above the upper third of the basal vein; first discoidal cell twice as high at base as at apex, receiving the nervulus at its basal third; recurrent nervure shorter than its distance from the first intercubitus.

Type from Weenen, Natal, March, 1924 (H. P. Thomasset).

This species is more or less similar to *C. trimaculatus* Cameron, but differs from the description of that species in having the hind tibiæ entirely pale. Cameron does not mention the front in his species, however, and might have failed to notice a striate sculpture of this part of the head, in which case it is possible that the two forms are not specifically distinct. From *C. striatus* Brues it differs by the entirely black stigma, maculate mesonotum and very much shorter face and clypeus.

Cardiochiles striatus Brues.

Ann. South African Mus., vol. 19, p. 95 (1924).

Six specimens from Umbilo, Durban, Natal (A. L. Bevis) collected during February, March, November and December; one from Widenham, Natal, December (A. L. Bevis); Umkomaas, South Coast, Natal, December (A. L. Bevis).

Cardiochiles bequaerti sp. nov.

♀. Length 5 mm. Fulvous and black. Head and antennæ, except a triangular mark at each side of the clypeus which includes all of the face below the level of the eyes, black; all coxæ and basal joint of trochanters, hind tarsi, tip of the hind tibiæ and fourth and following tergites black. Remainder of body fulvous; the legs more testaceous, including the tibial spurs. Wings subhyaline basally, dark apically; stigma black; veins piceous, yellowish to the base of the basal vein. Head fully twice as broad as thick, smooth and highly polished above; face minutely punctate above, more closely so near the top; clypeus subtriangular, as high as broad, together with the face one-third higher than the width of the face, Malar space as long as the first flagellar joint, with a linear groove. Eyes with unusually long, coarse hairs. Cheeks and outer orbits smooth; temples punctate and more or less distinctly striate. First joint of antennal flagellum nearly three times as long as broad; second fully as long, others gradually shorter. Mesonotum shining, faintly punctate; notauli deeply impressed, finely crenulate; median lobe with the pair of longitudinal grooves very broad and feebly impressed. Scutellum as long as broad, its basal groove broad, coarsely ridged; metanotum bifoveate. Propodeum with a large lozenge-shaped superomedian area, two lateral and one pleural area set off by very strong carinæ; the areas reticulate. Propleura smooth above and below, reticulate in the middle; mesopleura shining, with minute scattered punctures; its impression broad very shallow, except at the middle; smooth behind, reticulated anteriorly and at the middle; metapleura separated by a crenate line, smooth. First abdominal segment distinctly longer than wide. Longer spur of hind tibia two-thirds as long as the first tarsal joint. First section of the radius half as long as the second and slightly shorter than the second intercubitus; second cubital cell strongly narrowed toward the tip, second section of radius scarcely longer than the first intercubitus; nervulus entering the discoidal cell at its basal fourth; cubitus arising

just below the upper third of the basal vein; recurrent nervure received its own length before the end of the first cubital cell, two-thirds as long, as the lower section of the basal vein; submediellan cell in hind wing two-fifths as long as the mediellan.

Type from Belgian Congo; Lubumbashi, Katanga, January 18, 1921 (Mich. Bequaert). The long face and black-tipped hind tibiæ will distinguish this species from any others known from this region. It is also an unusually small form.

Cardiochiles tegularis Brues.

Ann. South African Mus., vol. 19, p. 100 (1924).

Weenen, Natal. Four specimens collected during November and December by H. P. Thomasset, one at an altitude of 2840 feet. From the Imperial Bureau of Entomology.

Cardiochiles nigromaculatus Cameron.

Rec. Albany Mus., vol. 1, p. 170 (1905).

An example from Weenen, Natal, December (H. P. Thomasset) forwarded by the Imperial Bureau of Entomology agrees so minutely with Cameron's description that it is undoubtedly this species. The following characters not mentioned by Cameron may be added. Head above and antennal basin entirely smooth; clypeus about twice as broad as high, distinctly punctate laterally; malar space shorter than the basal width of the mandible, with furrow; face including clypeus as high as wide. Mesonotum not distinctly punctate, grooves on middle and lateral lobes distinct; scutellum smooth, its basal groove broad, coarsely crenulate. First section of radius nearly half as long as the second which is twice as long as the second intercubitus; cubitus arising at the upper third of the basal vein; first discoidal cell half as high at apex as at base; submediellan cell in hind wing barely less than half as long as the mediellan.

In my key to South African species (Ann. South African Mus., vol. 19, p. 92) this will run to *C. fossatus* Brues from which it differs widely in color and in having the two basal joints of flagellum of equal length.

Cardiochiles fossatus Brues.

Ann. South African Mus., vol. 19, p. 97 (1924).

Umbilo, Durban, Natal, December 6, 1914 (A. L. Bevis).

Cardiochiles longipennis Brues.

Ann. South African Mus., vol. 19, p. 98 (1924).

Three specimens from the Belgian Congo; Lubumbashi, Katanga, March, April and November (Mich. Bequaert), given me by Dr. Jos Bequaert. Two are males and agree closely with the type from Zululand, except that the mesosternum is black. The female has the entire head, mesonotum, scutellum and mesopleuræ black. This is an unusually large species ranging from 7–8 mm. in length.

Disophrys Förster.

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 246 (1862).

Disophrys lutea Brullé.

Hist. Nat. Ins. Hymèn., vol. 4, p. 506 (1846) (*Agathis*).

As indicated in the accompanying catalogue this species is very widespread in Africa and the adjacent islands, and has been described under several names. In the present series there are seven males and two females from widely separated localities. Uganda; Entebbe (C .C. Gowdey): Zanzibar; Pemba Is. (H. J. Snell): Natal; Weenen (H. P. Thomasset) and Durban (A. L. Bevis and C. N. Barker).

Disophrys nataliensis Szépligeti.

Fermes, Füzetek, vol. 25, p. 71 (1902).

This stout species is represented in the material before me by two males from Salisbury, Rhodesia, one reared from a "yellow Lasiocampid" and another from "Gonometra sp" by J. O' Neil.

Disophrys dichroa Brullé.

Hist. Nat. Ins. Hymèn., vol. 4, p. 485 (1846) (*Agathis*).
Cameron, Rec. Albany Mus., Grahamstown, vol. 1, p. 158 (1905) (*Microdus bipustulatus*).

Six specimens representing both sexes from Durban, Natal; May, June, August, October and December (C. N. Barker and A. L. Bevis).

Megagathis Kriechbaumer.

Berliner Ent. Zeits., vol. 39, p. 311 (1894).

Megagathis schoutedeni Szépligeti.

Rev. Zool. Africaine, vol. 3, p. 415 (1914).

One female, Durban, Natal (C. N. Barker) from the Durban Museum. This species was described from the Belgian Congo.

Megagathis nataliensis Kriechbaumer.

Berliner Ent. Zeits., vol. 39, p. 312 (1894).

Five females and four males from Durban, Natal; February, April, September and December (C. N. Barker).

Hyrtanommatium Enderlein.

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 166 (1920).

Hyrtanommatium terebrator Brues.

Ann. South African Mus., vol. 19, p. 86 (1924) (*Euagathis*).

This species is very similar to *H. crassum* Enderlein, the type of the genus described from the Gold Coast. I have seen seven additional females from the type locality, Durban, Natal (C. N. Barker) forwarded by the Durban Museum and also a male from the same place To judge from Enderlein's description the two forms are distinct although of the same size and color, and may be distinguished as follows:

Vertex with the ocellar prominence acutely produced backwards; abdomen smooth and shining............... *H. crassum* Enderlein.
Vertex with an erect tubercle, not directed backwards; first and second segments of abdomen punctate.............. *H. terebrator* Brues.

The male is similar to the female except that the abdomen is blackened on its apical half.

Bassus Fabricius.

Syst. Piezatorum, p. 93 (1804)
Microdus of authors.

Bassus (Microdus) aciculatus sp. nov.

♀. Length 5 mm.; ovipositor nearly as long as the body. Pale fulvous, the antennæ black; sheaths of ovipositor fuscous. Wings subhyaline, slightly infuscated, more or less yellowish at the base;

costa and stigma piceous; venation pale brown. Head, thorax and legs covered with rather dense short white hairs. Head smooth above; supra-antennal impressions rather deep; front without trace of marginal carina; face shining, faintly punctate; as wide between the eyes as high from antennæ to margin of clypeus. Eyes oval, one-third longer than the strongly oblique malar space. Antennæ 29-jointed, much shorter than the body; first joint of flagellum four times as long as thick, as long as the scape and pedicel together, following ones shorter, all much longer than thick. Mesonotum shining, nearly smooth, gently and evenly convex, notauli forming discrete crenulated lines anteriorly, broader and smooth behind where they curve inward to meet in a gentle depression just behind the middle; scutellar groove with four large foveæ. Propodeum short, abruptly truncate behind; sharply, irregularly reticulate, with an elongate median area extending from base to apex. Propleura sparsely punctate above, smooth below; mesopleura shining, faintly punctate, its furrow short, broad and shallow, not crenulate; sides of propodeum finely punctate, spiracle large, oval. Legs very stout, hind femur fully one-third as wide as long; longer spur of hind tibia distinctly less than half the length of the metatarsus; all tarsal claws simple. Abdomen short and stout, as long as the thorax; first segment slightly longer than broad at apex, sides straight, the base a little more than half as broad as apex; surface finely longitudinally striate, the striæ anastomosing to some extent; extreme apex smooth; remainder of abdomen smooth and highly polished, with indistinct sutures; second tergite three times as broad as long, with a broad shallow transverse impression across the middle. First section of cubitus represented by a stump at base, but none at apex; second cubital cell very minute, with a long petiole above; radial cell very narrow, no broader than the antennal flagellum; nervulus very strongly oblique, postfurcal by half its length; nervellus arising at the lower corner of the third discoidal cell. Submediellan cell in hind wing half as long as the mediellan.

Type from Tanganyika Territory; Morogaro, February (A. H. Ritchie). The specimen bears the label, "from pupa of Erias." So far as I can ascertain this is the first species of this genus to be bred from Erias. The *Rhogas kitchneri* Dudgeon and Gough bred from this host appears to be a Microbracon without question.

The present form differs from *B. macronura* Szépligeti by the smooth, not crenulate mesopleural furrow, the entirely smooth second tergite and completely yellow hind tibiæ. From *B. post-*

furcalis Szépligeti it differs by its entirely yellow color with lightly infuscated wings, the absence of any furrow on the middle lobe of the mesonotum and very evident mesopleural furrow.

Bassus (Microdus) antefurcalis Szépligeti.

Mitt. Zool. Mus., Berlin, vol. 7, p. 220 (1914).

A male and female, bred from *Crocidolomia binotalis* by C. Mason at Namiwawa.

Crassomicrodus Ashmead.

Proc. U. S. Nat. Mus., vol. 23, p. 128 (1900).

Crassomicrodus pumilus Szépligeti.

Entom. Mitt., vol. 2, p. 385 (1914) (*Epimicrodus*).

One female and a male from Weenen, Natal, July and January (H. P. Thomasset).

The male is like the female except that the areolet in the wing has entirely disappeared and the tip of the abdomen is black. The second to fifth tarsal joints of the hind leg are pale at the extreme base in both sexes, giving the tarsi a distinctly annulate appearance.

This species may not be a true Crassomicrodus on account of the long ovipositor. As Bradley pointed out (Psyche, vol. 23, p. 139 (1916) Crassomicrodus will have to replace Epimicrodus in the sense of Ashmead and Szépligeti.

Hormagathis gen. nov.

Body rather short and stout, with stout legs, the hind pair noticeably thickened. Head strongly transverse, temples scarcely developed; ocelli on a slight elevation; no trace of any carinæ on the front or vertex; head in front view not quite so high as broad, greatly narrowed below the small eyes; palpi simple; antennæ as long as the body, 34-jointed, the apical joints submoniliform. Mesonotum as broad as long, feebly trilobed, the notauli meeting before the scutellum; propodeum strongly convex, not areolated; mesopleura with furrow. Abdomen convex above, depressed at base, more or less parallel-sided; first segment very broad at base; suturiform articulation slightly and broadly impressed, the second and third segments each with a similar transverse groove at the middle; first three segments longi-

tudinally striated; following ones gradually narrowed; ovipositor as long as the body. Tarsal claws not split nor toothed but with a broad basal lobe. Radial cell very narrow; second cubital cell triangular; first cubital fused with the first discoidal; nervulus postfurcal; radial cell in hind wing narrowed apically.

Type *H. mellea* sp. nov.

A member of the subfamily Agathidinæ as indicated by its very narrow radial cell, obsolete basal section of cubitus, minute second cubital cell and somewhat elongate, flat face with prominent clypeal foveæ, but differing from the other genera of this group in the form of the abdomen and from all except Braunsia Kriech. in the striate sculpture of the abdomen. The abdomen reminds one of the Horminæ or Doryctinæ. In Enderlein's key (Arch. Naturg., Jahrg 84A, Heft 11, p. 182; 1920) it will run to Ioxia Enderlein which is placed next Braunsia, with which he compares it. As Hormagathis is of entirely different habitus from Braunsia, it seems certainly not related to Ioxia.

Hormagathis mellea sp. nov.

♀. Length 4.6 mm. Dull fulvous; antennæ, tips of last tarsal joint on all legs and sheaths of ovipositor black. Wings pale fuscous; stigma and veins yellowish brown, and much lighter at the base of the wing. Head smooth and shining, the face with a very faint trace of punctulation; occiput weakly excavated medially; front with a slight depression above each antenna; ocelli in a flat triangle, the posterior pair nearly as far from one another as from the eye margin. Clypeal foveæ small, but deep; mandibles very small, apparently bidentate; labrum short; eyes oval, not much longer than wide, slightly longer than the malar space. Mesonotum smooth, without median grooves on the middle lobe; notauli sharply crenulated, not deep or broad, meeting in a depressed area behind the center of the mesonotum. Scutellum with a deep, curved, foveate groove at the base. Propodeum reticulated, the lines more or less longitudinal and transverse although there are no distinct carinæ in either direction. First segment of abdomen one-fourth broader at apex than at base, with a carinate elevation extending backwards from each anterior angle nearly to the middle of the segment; basal middle smooth, the remainder finely longitudinally striated; second segment as long and as wide as the first, finely striated, the suturiform articulation curved backwards at the sides, broad and shallow, the striæ extending across it; at the middle of the second segment there is a similar transverse groove

which curves backward medially to the posterior third of the segment. Third segment slightly shorter than the second and as wide; its striæ finer and disappearing before the hind margin; at the middle with a straight suture like that on the second segment; following segments much shorter, smooth, narrowing to a point, smooth and polished. Sheaths of the ovipositor rather densely hairy above. Pleuræ smooth and shining, the mesopleura very faintly and sparsely punctate; metapleura and sides of propodeum distinctly punctate. Hind legs quite considerably thickened, their tibiæ densely pubescent, tibial spurs stout, finely bristly, the longer one-half the length of the metatarsus which is nearly as long as the following joints together. Radius arising at the middle of the stigma, the radial cell very narrow; second cubital cell small, triangular, with a thickened petiole above which is longer than the minute first section of the radius.

Type from Doonside, Natal, January 13, 1917 (A. L. Bevis).

Braunsia Kriechbaumer.

Berliner Ent. Zeits., vol. 39, p. 63 (1894).

Braunsia partita sp. nov.

♂. Length 8 mm. Head, thorax, hind legs, including coxæ and abdomen beyond third segment, black; cheeks, mouthparts, tegulæ and four anterior legs, including coxæ, fulvous; basal three segments of abdomen fulvo-ferruginous, the first stained with fuscous medially. Base of wing to nervulus pale yellow; remainder blackish, with a complete transverse pale band that includes the stigma, first and second cubital cells and base of the apical discoidal area; hind wing pale on basal third and with an elongate pale spot in the radiellan cell. Head polished above, supra-antennal impressions deep; malar space smooth, convex, one-third as long as the eye; face as long as the width between the eyes, highly polished; basal joint of flagellum the longest, fully three times as long as thick, following rapidly shorter, none less than twice as long as thick. Lateral pronotal pits large, not meeting medially; mesonotum polished; grooves of median lobe very clearly impressed, notauli deep. Propodeum with an irregular carina which is distinct only on the basal fourth; reticulate laterally at the base, with several coarse transverse wrinkles at the middle and more or less clearly areolate apically. First abdominal tergite two and one-half times as long as wide at apex, gradually narrowed to the base; apical third finely striated; basal two-thirds with two stout carinæ and a

weaker median carina between them near the middle of the segment; second and basal half of third tergite closely evenly striate; apical section of third aciculate with the tip smooth; transverse impressions of both segments distinctly beyond the middle at about the apical three-fourths. Body hairs grayish white; yellow on the anterior legs, black and very dense on the hind ones. Nervulus postfurcal by half its length; first section of cubitus represented by a stump at both base and apex; areolet five-sided, narrowed above, with a stump externally above the middle.

Type from Natal; Durban, July (C. N. Barker).

This species is similar to *B. sjöstedti* Szépligeti, but differs by its black head and black hind legs, including the coxæ; also the stigma is yellow and the pale band below it much more extensive. From *B. excelsa* Brues it differs in the color of the head, abdomen and legs and the second cubital cell is broadly five-sided, not triangular.

Braunsia metanastriæ sp. nov.

♂. Length 10 mm. Head and thorax, including tegulæ, abdomen beyond third segment, and hind legs including coxæ, black. Middle coxæ piceous; cheeks, mouthparts and extreme base of hind tibiæ yellowish. Four anterior legs and three basal tergites bright fulvous. Wings yellow to the second intercubitus, black beyond; color of hind wing similar, the apical fourth dark. Head polished frontal impressions rather shallow except for the deeply excavated channels to the side of the antennal tubercles. First and second joints of antennal flagellum equal, each nearly three times as long as thick, following gradually shorter, but all more than twice as long as thick. Face shining, sparsely, but distinctly punctulate; malar space half as long as the eye; face as high as the width between the eyes. Lateral impressions of pronotum large, but widely separated medially. Notauli very deep; grooves of middle lobe of mesonotum sharply impressed, well separated. Propodeum smooth at base, with a very short median carina; at middle irregularly transversely wrinkled, apically with three short longitudinal carinæ medially, apical half of first, all of second and third, tergite, except extreme apex uniformly and rather coarsely striate; lateral carinæ of first strong on basal two-thirds; median one rather strong on apical two-thirds; transverse impression of second tergite well beyond the middle; that of the third tergite at the apical third, very broad and extremely shallow; nervulus postfurcal by half its length; first section of cubitus represented by a short stump

at base and a longer one at apex; second cubital cell five-sided, narrower above, externally with an angulation just above the middle, but without stump of a vein.

Type from Uganda; Entebbe, (?) May (S. A. Neave). Bred from *Metanastria indecora* Walker.

This species resembles *B. mimetica* Brues, but differs in having the wings yellow with the apical third black, by the much coarser striation of the abdomen, the pale four anterior legs and fulvous abdomen. The abdominal striation is unusually coarse and is uniform on all three segments.

Braunsia pleuralis sp. nov.

♀. Length 10 mm.; ovipositor as long as the body. Head, front legs, anterior part of prothorax, middle knees and middle tibiæ yellow; antennæ, meso- and metanotum, scutellum, mesopleuræ, hind and middle legs including coxæ, black; propodeum, metapleuræ, and abdomen to middle of third segment ferruginous; apex of abdomen piceous. Wings yellow at base as far as the nervulus; black beyond, with a complete yellow cross-band below the stigma and a large oval pale yellow area near apex; stigma entirely yellow; hind wing dark, pale at extreme base and with an incomplete pale band anteriorly before apex. Frontal impressions deep. Face long, distinctly higher than the width between the eyes; malar space nearly as long as the eye; face smooth and shining; first flagellar joint slightly longer than the second, three times as long as thick. Pronotal impressions large, almost meeting medially above. Mesonotum polished, grooves of median lobe shallow, indistinct anteriorly. Propodeum almost entirely smooth, with a few transverse wrinkles at the middle and a faint, very short median carina at the extreme base. Mesopleural furrow linear, smooth, without the usual crenulations. Apical half of first tergite coarsely striate, second and especially the third more finely so, the second section of the third aciculate beyond the transverse groove and smooth on apical third. First tergite with the lateral ridges strongly elevated basally and obliquely extended to the hind angles behind; median carina noticeable only near the middle of the tergite which is scarcely more than twice as long as thick and strongly constricted basally so that the lateral edges are distinctly concave. Transverse impression of second tergite at the apical third; of the third slightly behind the middle. Second cubital cell unusually broad above, the outer side slightly angulate and with a very short stump of a vein at the middle; first section of cubitus represented by

a long stump at both base and apex; nervulus postfurcal by one-third its length.

Type from Uganda; Kampala, November.

This species resembles *B. kriegeri* Enderlein but differs conspicuously in color, especially in the very strikingly bicolored thorax, yellow head and black hind legs; structurally the grooves on the mesonotum are not sharply impressed and the divisions of the second tergite are not of equal length.

Subfamily MICROGASTRINÆ

Mirax Haliday.

Entom. Mag., vol. 1, p. 263 (1883).

Mirax africana sp. nov.

♂. Length 1.7 mm. Yellowish brown; head, legs, basal two joints of antennæ and sides of first abdominal segment testaceous; propodeum blackened at apex. Wings hyaline, veins and stigma pale testaceous. Head opaque, without median groove on the vertex; occiput deeply emarginate. Head wide behind the eyes, the temples rather short and obliquely narrowed; ocelli in a small equilateral triangle which is about as long as its distance from each eye; face somewhat shining, especially on the clypeus which is convex and very distinctly separated from the face; cheeks shining; malar space as long as the second antennal joint, above with a distinct furrow which does not reach the base of the mandible. Antennæ shorter than the body, unmistakably 14-jointed, with no indication of division of any of the flagellar joints; first three flagellar joints of equal length, the fourth and following growing shorter and more slender. Notauli very distinct anteriorly, less so behind; mesonotum and central part of scutellum minutely granular, subopaque; scutellum depressed at the sides, with a large subtriangular, smooth, margined impression on each side and a pair of small round foveæ at apex, the two enclosed together in an oval margined line; postscutellum with an oval impression on each side. Propodeum with distinct median and a lateral longitudinal carina; more or less irregularly reticulate between the carinæ, more coarsely so behind. Mesopleura large, smooth and highly polished. First abdominal segment with the dorsal plate narrow; second not membranous except laterally at the sides. Stigma less than half as wide as long, emitting the intercubitus at its middle; base of radial vein scarcely indicated; nervulus postfurcal by its own

length; cubitus arising at the upper fourth of the basal vein; recurrent nervure nearly parallel with the basal and intercubitus; received two-thirds its length before the tip of the cubital cell; cubitus extending beyond the cell only as a short spur; submedian cell in hind wing nearly half as long as the median.

Type from Umbilo, Durban, Natal, August 23, 1914 (A. L. Bevis).

This is apparently a quite typical species of the genus in important characters. It differs from the South American *M. brasiliensis* Brues by the absence of a groove at the base of the scutellum, but as this is the only other species of the genus which I have seen, I do not know how important this distinction may be. This is the first species from this region; the few others known are pa æarctic, nearctic and neotropical.

SUBFAMILY METEORINÆ.

Meteorus Haliday.

Entom. Mag., vol. 3, p. 24 (1835).

Eight of the African species are included in the following key, four of which are hitherto undescribed. Unfortunately some species have been only briefly characterized and as the members of this genus are rather variable in color and difficult to distinguish I have not attempted to include all in the key since several are unknown to me in nature.

1. Head, thorax and abdomen black and reddish; abdomen black, with the petiole white....................................2.
   Not tricolored..3.
2. Mesonotum densely punctate.......... { *tricolor* Szépligeti. / *flavicornis* Szépligeti. }
   Mesonotum in great part smooth and shining, the middle lobe rugose behind......................*durbanensis* sp. nov.
3. Thorax and abdomen extensively marked with black, face, including clypeus, as wide as high..........*trilineatus* Cameron.
   Body brownish yellow, at most the postpetiole dark..........4.
4. Mesonotum densely and evenly rugose, its surface nowhere distinctly shining.......................................5.
   Mesonotum not evenly rugose, the median lobe in front and the lateral lobes, especially the latter, shining and feebly punctate; ocelli small, removed from the eye by more than their own diameter............ ....*neavei* sp. nov.

5. Second section of radius twice as long as the first, nervulus in hind wing antefurcal by its own length; longer spur of hind tibia about half as long as the metatarsus......*testaceus* Szépligeti.
   Second section of radius less than twice as long as the first; nervulus in hind wing antefurcal by less than its own length; tibial spurs decidedly less than half as long as the metatarsus....6.
6. Antennæ pale; postpetiole irregularly striate; thorax with a narrow black band behind the scutellum........*fasciatus* sp. nov.
   Antennæ black beyond the scape; postpetiole very regularly striate; thorax without black band behind the scutellum.
   laphygmarum sp. nov.

Meteorus durbanensis sp. nov.

♀. Length 4 mm.; sheaths of ovipositor nearly as long as the abdomen. Black with ferruginous and yellow markings. Ferruginous as follows; a spot behind and one above the eye, line between meso- and metapleura, ovipositor: yellow on face below, propleuræ below, coxæ and legs, except hind tarsi and their tibiæ above which are blackened. Wings hyaline, stigma and veins piceous, the basal vein and first section of cubitus much lighter. Basal half of first abdominal segment whitish. Head somewhat less than twice as wide as thick; smooth above and behind, marginal carina very strong; malar space very short; face quite distinctly transversely striate; clypeus very broad, convex, its foveæ deep and widely separated. Ocelli small, the posterior pair separated from one another and from the eye by almost twice their own diameter. Antennæ about 27-jointed; first flagellar joint as long as the second, nearly three times as long as thick; following shorter and thinner; all fully twice as long as thick. Mesonotum highly polished, faintly punctulate, notauli weakly impressed; middle lobe behind the middle shallowly rugose reticulate. Scutellum shining, its basal groove with six elongate foveæ. Propodeum coarsely reticulate, its posterior slope with a strongly marked median impression which is more finely sculptured. Propleura coarsely wrinkled, with a smooth band above. Mesopleura rather densely punctulate, with a large oval smooth area behind. Hind coxæ smooth and shining. First abdominal segment evenly widened behind; coarsely and evenly striate from near the base, spiracles slightly tuberculate; second segment clearly wider than long. Stigma nearly one-fourth as wide as the greatest width of the wing; first section of radius three-fourths as long as the second; third nine times as long as the second;

second cubital cell unusually short, the upper side only one-half as long as the basal; apical side fully as long as the lower; recurrent nervure entering the second cubital cell near its basal corner; nervulus postfurcal by its own length, entering the basal fourth of the discoidal cell. Radial cell in hind wing not constricted.

Type from Natal; Umbilo, Durban, October 12, 1919 (A. L. Bevis).

Meteorus testaceus Szépligeti.

Mitt. Zool. Mus. Berlin, vol. 7, p. 228 (1914).

One female. Uganda; Kampala, July (E. Hargreaves); bred from "unidentified furry caterpillar feeding on grass." The cocoon which accompanies the specimen is pale brownish, of the usual type with a suspensory silken thread. This may not be Szépligeti's species but agrees with his description so far as that extends. The type was from Langenburg, British East Africa.

Meteorus fasciatus sp. nov.

♀. Length 3.5–3.7 mm. Pale yellow, antennal flagellum more brownish. Ocellar spot slightly infuscated; tegulæ and postpetiole, except at tip, piceous; the narrow sclerite just behind the scutellum shining black for its entire length across the thorax. Basal line of propodeum also more narrowly black or dark brown. Head twice as broad as thick, the hind margin with a very distinct raised line. Vertex and head behind smooth, with short yellowish pubescence. Ocelli very large, oval, the hind ones separated by their own length, but closer to the eye-margin; face shining, faintly and more or less transversely striate; malar space very short, clypeal foveæ large and deep. First and second joints of flagellum equal, each fully three times as long as thick; third and fourth slightly shorter; those beyond growing rather rapidly shorter, but all considerably longer than broad. Mesonotum evenly rugose, dull; notauli scarcely indicated; scutellum strongly convex medially, shining. Propodeum very irregularly reticulate, more coarsely so toward the posterior extremity; slightly excavated medially on the posterior slope. Propleura closely reticulate except for a smooth space above; mesopleura similarly sculptured, dull, with a shining nearly smooth area at the middle; without furrow. Posterior coxæ granulate, not shining. Petiole of abdomen as long as the propodeum, twice as long as broad at tip, evenly widened from the scarcely prominent spiracles to the tip;

postpetiole striate, the striæ much closer together medially, more widely separated toward apex where some of the striæ do not reach the margin. Gaster smooth and polished; second segment nearly half longer than wide. Legs slender. Wings hyaline, with pale brownish stigma and luteous veins. Stigma nearly one-fourth as broad as the greatest width of the wing; first section of radius three-fifths the length of the second. Upper outer corner of second cubital cell forming almost a right angle, its basal and lower sides equal, the lower distinctly arcuate; apical side clearly shorter than the basal. Recurrent nervure entering the second cubital cell very near its base; nervulus entering the basal fourth of the discoidal cell. Radial cell in hind wing not at all constricted medially. Ovipositor sheaths as long as the thorax.

♂. Differs from the female in having the ocellar space more distinctly blackened, the sides of the second abdominal segment and apex of the third infuscated.

The eyes in both examples show brilliant blue, green and black reflections, possibly due to the way in which they may have been dried.

Type ♀ and paratype ♂ from Natal; Wienen, May, 1924 (H. P. Thomasset).

Meteorus laphygmarum sp. nov.

♀. Length 4.5 mm.; ovipositor sheaths as long as the thorax. Light yellow, the tarsi brown and the antennal scape black; a black streak along the inner edge of each ocellus, postpetiole at each side just before the tip and a faint spot at the side of the gaster near the middle dark brownish. Wings hyaline, stigma and veins pale fuscous. Head fully twice as wide as thick, with a very distinct marginal line behind. Ocelli very large, oval, the posterior pair separated by their own diameter and a little closer to the eye margin. Occiput and head behind smooth, polished; front shining, faintly transversely wrinkled. Face minutely, but distinctly transversely aciculate or wrinkled. Clypeal foveæ moderately large, deeply impressed; face including clypeus, considerably higher than wide; malar space very short. Antennal flagellum stout, the first and second joints equal, about twice or two and one-fourth times as long as thick; following joints shorter but remaining nearly twice as long as thick to beyond the middle of the flagellum. Mesonotum rugose, more coarsely behind and at the sides, subopaque. Basal scutellar groove deep and broad, sexfoveate; scutellum moderately convex, subshining. Propodeum

coarsely reticulate, broadly and very distinctly impressed medially except at the base. Propleuræ punctate-reticulate, with a shining, nearly smooth band along the upper border; mesopleura irregularly reticulate below, shining and more or less irregularly punctate above; hind coxæ finely granular, distinctly shining. Abdominal petiole gradually enlarged behind the middle, without distinct tubercles at the spiracles; postpetiole regularly and evenly striated, the lines evenly spaced across its disk; second segment one-half longer than broad. Stigma one-fifth as broad as the greatest width of the wing; first section of radius two-thirds as long as the second; third very faintly sinuate. Second cubital cell distinctly oblique and narrowed apically; upper edge as long as the outer; lower indistinctly shorter than the first intercubitus; nervure joining the cubitus slightly but distinctly beyond the first intercubitus. Nervulus postfurcal, by nearly its own length, entering at the basal fourth of the discoidal cell. Radial cell in hind wing not contracted medially.

Type from Rhodesia; Salisbury, January, reared from *Laphygma exigua* Hübn. As there is a North American species described by Viereck as *Meteorus laphygmæ* I have given the name *M. laphygmarum* to the present one. *M. laphygmæ* was bred from *L. frugiperda* Sm. and Abb., the most abundant Laphygma in the United States although *L. exigua* occurs in North America also.

Meteorus neavei sp. nov.

♀. 4 mm.; ovipositor sheaths about as long as the abdomen. Light yellow, with the antennal scape and the flagellum apically more or less infuscated. Ocellar spot and hind tarsi usually dark brown. Tegulæ dark and the sides of the postpetiole and of the second tergite behind more or less infuscated. Sheaths of ovipositor piceous. Wings hyaline; stigma and veins light brown, the costa piceous. Head twice as broad as thick, above and behind shining, almost impunctate, margined behind. Ocelli smaller than usual, the posterior pair separated by the diameter of an ocellus and separated from the eye by a noticeably greater distance. Face shagreened, shining, without trace of transverse striation. Clypeus highly protuberant, its lateral foveæ rather small, deep. Malar space very short, cheeks shining, nearly smooth. Antennæ about 34-jointed; second joint of flagellum slightly longer than the first, three times as long as thick; those following gradually shorter and thinner, all fully twice as long as thick. Mesonotum shining, very feebly punctate, the posterior third of the

middle lobe finely rugose and not so shining. Basal groove of scutellum broad, with three or four longitudinal ridges on each side of the middle; scutellum polished, highly convex. Propodeum coarsely reticulate, with a very broad and shallow impression medially behind. Pleuræ shining; propleura nearly smooth; mesopleura finely rugose below, polished above. Hind coxæ smooth and shining; longer spur of hind tibia extending nearly to the middle of the metatarsus. Abdominal petiole coarsely and evenly striate, the striæ extending nearly to the base; evenly expanded behind from the basal fifth; spiracles slightly prominent, at the middle. Second segment as long as broad at apex. First discoidal cell distinctly petiolate above; first section of radius almost as long as the second; second cubital cell strongly narrowed apically and toward the top, its basal side twice as long as the upper one; apical side distinctly longer than the arcuate lower one and two-thirds as long as the basal; recurrent nervure entering the second cubital cell near to its basal corner; nervulus postfurcal by less than its own length, entering the discoidal cell at the basal fifth. Radial cell in hind wing gradually narrowed apically but not contracted medially.

♂. Essentially like the female.

Type ♀ and six paratypes, including two males, from Nyasaland; Mlanje, April 27, 1913 (S. A. Neave).

Meteorus trilineatus Cameron.

Rec. Albany Mus., Grahamstown, vol. 1, p. 242 (1905).

One male, Weenen, Natal, March–April (H. P. Thomasset).

This species, if I have correctly identified it, differs from *M. laphygmarum* Brues, which it resembles most closely, by its much darker color and broader face which is fully as broad as high, including the clypeus; the nervulus is very slightly postfurcal in the fore wing, and by more than its own length in the hind wing.

Dinocampus Förster.

Verh. Naturh. Ver. preuss. Rheinlande, vol. 19, p. 252 (1862).

There are two species in the material before me, distinguishable as follows:

Abdomen fulvous beyond the petiole, scutellum punctate; nervulus weakly postfurcal; first discoidal cell strongly petiolate above. *fulvogaster* sp. nov.

Abdomen entirely black; scutellum smooth medially; nervulus strongly postfurcal; first discoidal cell not petiolate above.
nigrogaster sp. nov.

Dinocampus fulvogaster sp. nov.

♂. Length 2.7 mm. Head, tegulæ, legs including coxæ and abdomen beyond the petiole fulvous; ocellar spots and entire thorax black; petiole of abdomen piceous; tarsi brown. Wings hyaline; costal vein black, stigma and venation light brown, the veins near the base of the wing still paler. Head very much contracted behind, with distinct marginal line; temples broad, as wide as the eye in dorsal view; ocelli in a rather flat triangle, the posterior pair one-third farther from the eye than from one another; surface punctate, coarsely on the shining vertex, finely on the subopaque, pale pubescent face; clypeus smooth, with broadly rounded edge; malar space two-fifths as long as the rather small oval eye, with a distinct furrow; head behind eyes shining, finely sparsely punctate. Antennæ filiform; scape scarcely twice as long as thick; first and third joints of flagellum of equal length, thrice as long as thick, the second joint quite distinctly longer. Pronotum rugose, with a pair of approximate foveæ above. Mesonotum and scutellum rather closely and finely punctate, shining; notauli distinct, but not broad nor deeply impressed. Scutellum with four large foveæ across the base; disc sharply convex. Propodeum evenly and rather finely reticulate, with a broad median impression on the posterior face, less pronounced and narrower on the upper face; in profile the posterior face is nearly vertical below, rounding off above to the somewhat shorter upper face; posterior angles not evident. Seen from the side the thorax is one-half longer than high, the mesonotum extended downwards in front so that its anterior portion lies in a vertical position; propleura closely evenly punctate; mesopleura more sparsely punctate above, reticulate punctate below, the impression very broad and extremely shallow. Petiole of abdomen longitudinally aciculated; gradually widened behind, with angular prominent spiracular tubercles just before the apical third; at least three times as long as broad at apex. Following segments smooth and polished, with the sutures scarcely noticeable; second segment nearly as long as the first and one-half longer than the remaining ones together. Radius arising just behind the middle of the stigma, its first section slightly more than half as long as the width of the stigma, second section evenly curved, meeting the costa halfway between the tip of stigma and wing tip; cubitus arising at the upper sixth of the

basal vein, its first section as long as the intercubitus and perpendicular to it; recurrent nervure interstitial, the cubitus obsolete beyond this point.

Type from Umkomaas, South coast of Natal, December, 1914 (A. L. Bevis).

Dinocampus nigrogaster sp. nov.

♂. Length 2.5 mm. Thorax and abdomen black; legs, including coxæ, but excepting the fuscous tarsi, tegulæ and head, except occiput and a large spot on the vertex, fulvo-ferruginous. Wings hyaline, costal vein piceous, stigma and venation testaceous. Occipital carina very strong; vertex finely punctulate; front highly polished and impunctate below the ocelli, finely rugulose on the sides; face rugulose. Antennæ 30-jointed, first flagellar joint distinctly shorter than the second, following joints growing shorter, but all considerably more than twice as long as thick. Pronotum bifoveate above. Mesonotum closely punctate; notauli very distinct but not conspicuous. Scutellum with four elongate foveæ at base, its disc entirely smooth and polished, evenly convex. Propodeum coarsely reticulated, the upper face convex; posterior one with a broad, shallow median excavation; in profile evenly rounded with the lower part of the posterior face vertical. Propleura reticulate striate; mesopleura reticulate above and below, smooth at the middle; mesopleural groove shallow and poorly developed. Venation as in *D. fulvogaster* except that the nervulus is postfurcal by more than half its length; the cubitus arises at the basal vein and its first section is longer than the intercubitus. Petiole of abdomen finely longitudinally aciculated, its spiracular protuberances inconspicuous; second segment less than half as long as the petiole; smooth and polished as are the remaining segments.

Type from Umbilo, Durban, Natal, September 7, 1919 (A. L. Bevis).

This species is very similar to the foregoing.

Subfamily HELORIMORPHINÆ

Helorimorpha Schmiedeknecht.

Hymen. Mitteleuropas, p. 523 (1907).
Cameron, Soc. Entom., Jahrg. 24, p. 9 (1909) (*Stictometeorus*).

Key to the African Species.

1. Body entirely luteous or orange yellow .... 2.
   At least the mesonotum and scutellum black .... 4.

2. Antennal flagellum entirely black... ....3.
   Antennal flagellum honey-yellow with the apical three or four joints black; second transverse cubitus hyaline at the middle; veins beyond the cells almost entirely obliterated.
   H. africana Brues.
3. Recurrent nervure interstitial with the first transverse cubitus.
   H. coffeæ Brues.
   Recurrent nervure received by the second cubital cell.
   H. lutea Szép.
4. *H. rufa* Cameron and *H. bicolor* Szépligeti which are unknown to me in nature differ from the other African species by the bicolored thorax; they are indistinguishable on the basis of the original descriptions.

Helorimorpha africana Brues.

Ann. South African Mus., vol. 19, p. 101 (1924).

Natal; Weenen. Two specimens, May (H. P. Thomasset).

Helorimorpha lutea Szépligeti.

Ann. Mus. Nat. Hungarici, vol. 11, p. 608 (1913) (*Stictometeorus*).

Natal; Umbilo, Durban. One specimen, December (A. L. Bevis).

Helorimorpha coffeæ Brues.

Ann. South African Mus., vol. 19, p. 103 (1924).

Natal; Doonside. One specimen, January (A. L. Bevis).

Helorimorpha rufa Cameron.

Soc. Entom., Jahrg. 24, p. 9 (1909) (*Stictometeorus*).

Natal, Durban. September to February (A. L. Bevis). Three specimens apparently of this species.

Family ALYSIIDÆ

Cœlalysia Cameron.

Ann. Transvaal Mus., vol. 2, p. 212 (1911).
Turner, Bull. Ent. Res., vol. 8, p. 177 (1917).

Cœlalysia bicolor Szépligeti.

Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, p. 417, ♂. (*Idiasta*).

Three males from Kampala, Uganda, taken during September, November and January; forwarded by the Imperial Bureau of Entomology. The hind tibiæ are sometimes partly or wholly black. One male from Walikale, Congo, January (Bequaert) has the first three abdominal segments yellow and the striation of the first segment much finer.

Cœlalysia nigriceps Szépligeti.

Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, p. 417 ♀ (*Idiasta*).

One female from Rungu, Congo (Rodhain), given me by Dr. Bequaert. The white on the antennæ is a subapical annulus including nine or ten joints.

Only females of this species and males of the preceding one are known and it is possible that they are sexes of a single form.

PART II.

CATALOGUE OF THE GENERA AND SPECIES OF BRACONIDAE OF AFRICA AND THE ADJACENT ISLANDS, INCLUDING MADAGASCAR.

In addition to the continental Ethiopian species this catalogue includes also those that have been recorded from Madagascar since some species are known to occur in both areas and it is probable that the range of a number of others will later be found to extend similarly from the true Ethiopian to the Malagasy region. From the smaller oceanic islands like Madeira and the Seychelles only a very few species have been recorded, but several of these at least occur on the continent and it has seemed best to include such islands also. The same has been done for northern Africa. The palaearctic complexion of the north African fauna is of course very marked especially in Algiers and Tunis, but this condition is less marked in Morocco and still less so toward the east where the Egyptian fauna merges into that of the regions to the south. With this in mind, I have therefore after considerable hesitance decided to include all the continental species. The Egyptian fauna has received almost no attention, but that of eastern Equatorial Africa is much better known, especially that of Tanganyika Territory which was formerly German East Africa. Many species are known from southern Africa, mainly from Natal, Transvaal and the Cape Province. In western equatorial Africa the faunæ of Camerun and Togo are best known and a smaller number of species have been recorded from the Belgian Congo.

The generic position of some of the species described by the older authors is doubtful and it is inevitable that some of these should be placed only on a tentative basis. This is especially true of several described by Lucas (1846) although Brullé's species described at the same time are nearly always easily recognizable and may even commonly be referred to modern genera on the basis of the original descriptions. With the exception of several species of the older entomologists, to the descriptions of which I have not had access, an attempt has been made to assign generic locations to all the species. Thus the numerous species of the old genera "Bracon" and "Agathis" have been placed, occasionally with some doubt, in modern genera.

New names for a few obvious homonyms are proposed, although as indicated on another page (315) this has not been done for the genus Iphiaulax, as it seems probable that this enormous group may in the future be subdivided upon a rational basis into a number of genera

which will include some of the numerous generic names already proposed. Among the several generic segregates of Iphiaulax, Szépligeti has used the same specific names quite frequently and as it seems impossible to accept most of these segregates as they now stand, several duplications of specific names appear under this genus. Considering the dubious nature of these genera such a procedure is very unfortunate and will finally result in some homonyms, their number depending upon the number of genera finally accepted.

In most cases the known distribution of each species is cited by political subdivisions, but in the case of some widespread forms such general terms as "Equatorial Africa" and "Southern Africa" have been used for the sake of brevity when it appears that such designations are reasonably satisfactory. A very considerable number of forms appear in both the eastern and western sections of the equatorial belt and a few extend from East Africa to the Cape. The number thus far found to be common to east Africa and Madagascar is surprisingly large.

The large number of species added to the African fauna in this one family during the past twenty years indicates very clearly the great activity of biological explorers and collectors on this continent and emphasizes also the great richness of its insect fauna.

Subfamily STEPHANISCINÆ

Stephaniscus Kieffer

André, Hymén Europe et Algérie., vol 7bis, pl. 478 (1904)
Szépligeti, Genera Insect., fasc. 22, p. 54 (1905) (*Schlettereriella*)
Schulz, Zool. Ann., vol. 4, p. 65 (1911) (*Psenobolus*)

oncophorus Schletterer — Cape Province

Berliner Ent. Zeit., vol. 33, p. 207 (1889) (*Stenophasmus*)
Enderlein, Arch. Naturg., Jahrg. 1901, vol. 1, Heft 3, p. 206 (1901) (*Stenophasmus*)
Szépligeti, Genera Insect., fasc. 22, p. 54 (1905) (*Schlettereriella*)
Schulz, Zool. Ann., vol. 4, p. 65 (1911) (*Psenobolus*)
Enderlein, Arch. Naturg., Jahrg. 78A, Heft 2, p. 3 (1912)

Ogmophasmus Enderlein

Arch. Naturg., Jahrg. 78A, Heft 2, p. 4, 13 (1912)
Cameron, Ann. Soc. Ent. Belgique, vol. 56, p. 371 (1912) (*Rhopalospathius*)

Type: *O. ingens* Enderlein

aurantiiceps CAMERON DIMA, BELGIAN CONGO

Ann. Ent. Soc. Belgique, vol. 56, p. 369 (1912) (*Rhopalospathius aurantieiceps*)

büttneri STADELMANN TOGO

Ent. Nachricht., vol. 19, p. 226 (1893) (*Stenophasmus*)
ENDERLEIN, Arch. Naturg., Jahrg. 1901, vol. 1, Heft 3, p. 206 (1901) (*Stenophasmus*)
ENDERLEIN, ibid., Jahrg. 78A, Heft 2, p. 13 (1912)

camerunus ENDERLEIN CAMERUN

Arch. Naturg., Jahrg. 1901, vol. 1, p. 209 (1901) (*Stenophasmus*)
ENDERLEIN, ibid., Jahrg. 78A, Heft 2, p. 13 (1912)

erythrothorax Cameron CONGO, ZULULAND

Ann. Soc. Ent. Belgique, vol. 56, p. 371 (1912) (*Rhopalospathius*)
Brues, Ann. South African Mus., vol. 19, p. 11 (1924)

flaviceps ENDERLEIN CAMERUN

Arch. Naturg., Jahrg. 78A, Heft 2, p. 13 (1912)

fülleborni ENDERLEIN TANGANYIKA TERRITORY

Arch. Naturg., Jahrg. 1901, vol. 1, Heft 3, p. 206 (1901) (*Stenophasmus*)
ENDERLEIN, ibid., Jahrg. 78A, Heft 2, p. 13 (1912)

ingens ENDERLEIN TOGO

Arch. Naturg., Jahrg. 1901, vol. 1, Heft 3, p. 207 (1901) (*Stenophasmus*)
ENDERLEIN, ibid., Jahrg. 78A, Heft 2, p. 13 (1912)

Doryctophasmus ENDERLEIN

Arch. Naturg., Jahrg. 78A, Heft 2, p. 18 (1912)
Type: *D. ferrugineiceps* Enderlein

africanus Brues ZULULAND

Proc. American Acad. Arts Sci., vol. 61, p. 206 (1926)

SUBFAMILY SPATHIINÆ

Spathius NEES

Nov. Act. Acad. Nat. Curios, vol. 9, p. 301 (1818)
Type: *S. exarator* Linnæus

apterus WOLLASTON MADEIRA

Ann. Mag. Nat. Hist. (3), vol. 1, p. 24 (1858)

caudatus SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 599 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 193 (1914)

flavicornis SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 599 (1913)

læviceps BRUES TRANSVAAL
Ann. South African Mus., vol. 19, p. 13 (1924)

pleuralis SZÉPLIGETI CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 193 (1914)

rufithorax SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 192 (1914)

striaticeps BRUES ZULULAND
Ann. South African Mus., vol. 19, p. 11 (1924)

testaceus SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 600 (1913)

transversalis SZÉPLIGETI TOGO
Mitt. Zool. Mus., Berlin, vol. 7, p. 193 (1914)

tricolor SZÉPLIGETI TOGO
Mitt. Zool. Mus., Berlin, vol. 7, p. 193 (1914).

trochanteratus SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 193 (1914)

Platyspathius VIERECK

Proc. U. S. Nat. Mus., vol. 40, p. 185 (1911)
Type: *P. pictipennis* Viereck

pictipennis VIERECK PORTUGUESE EAST AFRICA
Proc. U. S. Nat. Mus., vol. 40, p. 185 (1911)

SUBFAMILY HECABOLINÆ

Monolexis FÖRSTER

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 237 (1862)
Type: *M. fuscicornis* Förster

caudata SZÉPLIGETI MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 423 (1913)

Subfamily HORMIINÆ

Spathiohormius Enderlein

Arch. Naturg., Jahrg. 78A, Heft 2, p. 19 (1912)

Type: *S. ornatulus* Enderlein

dentatus Brues — Zululand
Ann. South African Mus., vol. 19, p. 14 (1924)

Hormiopterus Giraud

Ann. Soc. Ent. France, (4), vol. 9, p. 478 (1869)

Type: *H. olivieri* Giraud

alpicola Szépligeti — Kilimandjaro, 12,000 ft.
Mitt. Zool. Mus., Berlin, vol. 7, p. 202 (1914)

antennalis Szépligeti — Tanganyika Territory
Wiss. Ergebn, Reise Voeltzkow, vol. 3, p. 423 (1913)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 202 (1914)

capensis Brues — Cape Colony
Ann. South African Mus., vol. 19, p. 15 (1924)

caudatus Szépligeti — Tanganyika Territory
Mitt. Zool. Mus., Berlin, vol. 7, p. 202 (1914)

concolor Szépligeti — British East Africa
Rés. Sci. Voyage Alluaud, p. 179 (1914)

flavipes Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 409 (1911)

fuscipennis Szépligeti — Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 201 (1914)

guineensis Szépligeti — Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 202 (1914)

minor Szépligeti — Tanganyika Territory
Mitt. Zool. Mus., Berlin, vol. 7, p. 202 (1914)

niger Szépligeti — British East Africa
Rés. Sci. Voyage Alluaud, p. 178 (1914)

olivieri Giraud — Algeria (Europe)
Ann. Soc. Ent. France (3), vol. 9, bull, p. lxi (1857)
Giraud, ibid., (4), vol. 9, p. 478 (1869)
Giraud, ibid., vol. 61, p. 5 (1870)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 257 (1888)

orientalis SZÉPLIGETI — TANGANYIKA TERRITORY

Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 424 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 202 (1914)

persimilis SZÉPLIGETI — NYASALAND

Wiss. Ergebn. deutsch. Zentral-Afrika Exped, 1907–08, vol. 3, p. 409 (1911)

rufescens SZÉPLIGETI — TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 202 (1914)

striatus SZÉPLIGETI — NYASALAND

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 409 (1911)

Hormius NEES

Nov. Act. Acad. Nat. Curios., vol. 9, p. 305 (1818)
NEES, Hymen. Ichneum. affin. Monogr., vol. 1, p. 153 (1834)

Type: *H. moniliatus* Nees

elegans SZÉPLIGETI — KENYA COLONY

Res. Sci. Voyage Alluaud, p. 177 (1914)

testaceus CAMERON — TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 195 (1911)

SUBFAMILY PAMBOLINAE

Pambolus HALIDAY

Ent. Mag., vol. 4, p. 40 (1836)

Type: *P. biglumis* Haliday

aciculatus BRUES — CAPE PROVINCE

Ann. South African Mus., vol. 19, p. 17 (1924)

flavicornis SZÉPLIGETI — KILIMANDJARO

Ann. Mus. Nat. Hungarici, vol. 11, p. 600 (1913)

pulchricornis SZÉPLIGETI — TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 600 (1913)

SUBFAMILY BRACONINÆ

Microbracon ASHMEAD

Bull. Colorado Biol. Assoc., vol. 1, p. 15 (1890)
JOHNSON, Entom. News, vol. 6, p. 324 (1895)
ASHMEAD, Proc. U. S. Nat. Mus., vol. 23, p. 138 (1900) (*Macrodyctium*)

ASHMEAD, ibid., t.c., p. 139 (1900) (*Bracon*)
ASHMEAD, ibid., t.c., p. 139 (1900) (*Habrobracon*)
ASHMEAD, ibid., t.c., p. 139 (1900) (*Tropidobracon*)
SZÉPLIGETI, Genera Insect., fasc. 22, p. 27 (1904) (*Bracon*)
NASON, Entom. News, vol. 16, p. 298 (1905) (*Liobracon*, nec Szépligeti)
VIERECK, Proc. U. S. Nat. Mus., vol. 44, p. 640 (1913) (*Amyosoma*)
CUSHMAN, Proc. Ent. Soc. Washington, vol. 16, p. 99 (1914) (*Habrobracon*)
VIERECK, Bull. 22, Connecticut State Geol. Nat. Hist. Survey, p. 182, 204 (1917).
MUESEBECK, Proc. U. S. Nat. Mus., vol. 67, Art. 8, p. 3 (1925)

Type: *M. sulcifrons* Ashmead.

albopilosus SZÉPLIGETI — TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 596 (1913) (*Bracon*)

alpicola SZÉPLIGETI — TANGANYIKA TERRITORY; 12,000 FT.
Mitt. Zool. Mus., Berlin, vol. 7, p. 188 (1914) (*Bracon*)

amaniensis SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol 7, p. 187 (1914) (*Bracon*)

annulicornis Brues — ZULULAND
Ann. South African Mus., vol. 19, p. 20 (1924)

auratus SZÉPLIGETI — KILIMANDJARO
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 34 (1910) (*Bracon*)

beneficientor VIERECK — PORTUGUESE EAST AFRICA
Proc. U. S. Nat. Mus., vol. 40, p. 182 (1911) (*Habrobracon*)

bilineatus SZÉPLIGETI — TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 597 (1913) (*Bracon*)

bipustulatus SZÉPLIGETI — ABYSSINIA
Ann. Mus. Nat. Hungarici, vol. 11, p. 597 (1913) (*Bracon*)

campyloneurus SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 187 (1914) (*Bracon*)

capillicaudis SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 186 (1914) (*Bracon*)

celer SZÉPLIGETI — NATAL
Boll. Lab. Gen. Agar., Portici, vol. 7, p. 101 (1913) (*Bracon*)

SILVESTRI, ibid., vol. 8, p. 122 (1914) (*Bracon*)
SILVESTRI, ibid., t.c., p. 331 (1915) (*Bracon*)
BRUES, Trans. American Acad. Arts & Sci., vol. 61, p. 211 (1926)

ceres BRUES — CAPE PROVINCE
Ann. South African Mus., vol. 19, p. 31 (1924)

constantinus STRAND — ALGERIA
Entom. Zeits. Stuttgart, Jahrg. 24, p. 219 (1910) (*Bracon*)

crocatus SCHMIEDEKNECHT — ALGERIA
Illustr. Wochenschr. Ent., vol. 1, p. 541 (1896) (*Bracon*)
MARSHALL, Hymén. Europe et Algérie, vol. 5bis, p. 255 (1898) (*Bracon*)

curticornis BRUES — CAPE PROVINCE
Ann. South African Mus., vol. 19, p. 26 (1924)

frontalis SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 188 (1914) (*Bracon*).

guineensis SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 188 (1914) (*Bracon*)

hector BRUES — NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 208 (1926)

hedwigiæ SCHMIEDEKNECHT — ALGERIA
Illustr. Wochenschr. Ent., vol. 1, p. 590 (1896) (*Bracon*)
MARSHALL, Hymén. Europe et Algérie, vol. 5bis, p. 257 (1898) (*Bracon*)

hieroglyphicus BRUES — ZULULAND, NATAL
Ann. South African Mus., vol. 19, p. 23 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 210 (1926)

hilarellus SchmIEDEKNECHT — ALGERIA
Illustr. Wochenschr. Ent., vol. 1, p. 529 (1896) (*Bracon*)
MARSHALL, Hymén. Europe et Algérie, vol. 5bis, p. 254 (1898) (*Bracon*)

howardi VIERECK — PORTUGUESE EAST AFRICA
Proc. U. S. Nat. Mus., vol. 40, p. 184 (1911)

jonesii BRUES — ZULULAND
Ann. South African Mus., vol. 19, p. 24 (1924)

kitcheneri DUDGEON & GOUGH — EGYPT
Bull. Soc. Ent. Egypte, Ann. 3, p. 140 (1914) (*Rhogas*)

DUDGEON & GOUGH, Agric. Journ. Egypt, vol. 3, p. 108 (1914) (*Rhogas*)
BRUES, Rept. Third Ent. Meeting Pusa, vol. 3, p. 1026 (1920)
RAMACHANDRO RAO, Mem. Dept. Agric Iraq Baghdad, No. 7, p. 30 (1921) (*Habrobracon*)

lagosianus SZÉPLIGETI — LAGOS
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 101 (1913) (*Bracon*)

latifasciatus BRUES — ZULULAND, NATAL
Ann. South African Mus., vol. 19, p. 22 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 210 (1926)

latilineatus CAMERON — CAPE PROVINCE
Arch. Math. Naturvidens., vol. 30, No. 10, p. 3 (1909) (*Bracon*)

lembaënsis CAMERON — BELGIAN CONGO
Ann. Ent. Soc. Belgique, vol. 56, p. 368 (1912)

maculiventris HOLMGREN — CAPE PROVINCE
Eugen. Resa, Ins., vol. 2, p. 423 (1868) (*Bracon*)
ROMAN, Ent. Tidskr., vol. 31, p. 114 (1910)

madagascariensis SZÉPLIGETI — MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 422 (1913) (*Bracon*)

maroccanus SZÉPLIGETI — MOROCCO
Ann. Mus. Nat. Hungarici, vol. 4, p. 588 (1906) (*Bracon*)

mauritanicus SCHMIEDEKNECHT — ALGERIA
Illustr. Wochenschr. Ent., vol. 1, p. 572 (1896) (*Bracon*)
MARSHALL, Hymén. Europe et Algérie, vol. 5bis, p. 256 (1898) (*Bracon*)

monitor BRUES — CAPE PROVINCE
Ann. South African Mus., vol. 19, p. 32 (1924)

notatus SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 186 (1914) (*Habrobracon*)

nundina SZÉPLIGETI — BRITISH EAST AFRICA
Rés. Sci. Voyage Alluaud, Hymen., p. 174 (1914) (*Bracon*)

opacus SZÉPLIGETI — NYASALAND
Wiss. Ergebn., deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 405 (1911) (*Bracon*)

pectoralis WESMAEL — ALGERIA (Europe)
Nouv. Mém. Acad. Sci. Belgique, vol. 11, p. 12 (1838) (*Bracon*)

MARSHALL, Trans. Entom. Soc. London, 1885, p. 16 (1885) (*Bracon*)
SZÉPLIGETI, Termes. Füzetek, vol. 19, p. 287, 361 (1896) (*Bracon*)

persimilis SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 599 (1913) (*Habrobracon*)

postfurcalis BRUES ZULULAND, NATAL
Ann. South African Mus., vol. 19, p. 28 (1924)
BRUES, Proc. American Acad. Arts. Sci., vol. 61, p. 210 (1926)

præceptor BRUES ZULULAND
Ann. South African Mus., vol. 19, p. 30 (1924)

propinquus CAMERON DELAGOA BAY
Arch. Math. Naturvidens., vol. 30, No. 10, p. 4 (1910) (*Bracon*)

puniceus SCHMIEDEKNECHT TUNIS
Termes. Füzetek, vol. 23, p. 246 (1900) (*Bracon*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 594 (1906) (*Habrobracon*)

quadripunctatus SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 597 (1913) (*Bracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 186 (1914) (*Bracon*)

recessus SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 598 (1913) (*Bracon*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 210 (1926)

rugosus SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 186 (1914) (*Habrobracon*)

sanctæ-crucis SCHMEIDEKNECHT ALGERIA
Illustr. Wochenschr. Ent., vol. 1, p. 590 (1896) (*Bracon*)
MARSHALL, Hymén. Europe et Algérie, vol. 5bis, p. 257 (1898) (*Bracon*)

sectator BRUES NATAL
Ann. South African Mus., vol. 19, p. 33 (1924)

sesamiæ CAMERON SOUTH AFRICA
Trans. South African Philos. Soc., vol. 16, p. 334 (1906) (*Bracon*)

sigitaliensis SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 187 (1914) (*Bracon*)

simulator SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 187 (1914) (*Bracon*)

somnialis Szépligeti — Assab, East Africa
Ann. Mus. Nat. Hungarici, vol. 11, p. 598 (1913) (*Bracon*)

suavis Szépligeti — British Southwest Africa
Beitr. Landf. Südwestafrika, vol. 1, p. 189 (1918)

suspectus Brues — Natal
Proc. American Acad. Arts Sci., vol. 61, p. 207 (1926)

thalassinus Schmiedeknecht — Algeria
Illustr. Wochenschr. Ent., vol. 1, p. 573 (1896) (*Bracon*)
Marshall, Hymén. Europe et Algérie, vol. 5bis, p. 257 (1898) (*Bracon*)

triangularis Szépligeti — East Africa, Madagascar
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 405 (1911) (*Habrobracon*)
Szépligeti, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 422 (1913) (*Habrobracon*)

tristis Szépligeti — Kilimandjaro, 12,000 ft.
Rés. Sci. Voyage Alluaud, Hymén., p. 173 (1914) (*Bracon*)

uelleburgensis Szépligeti — Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 188 (1914) (*Bracon*)
Ann. Mus. Nat. Hungarici, vol. 11, p. 598 (1913) (*Bracon*)
Ann. Mus. Nat. Hungarici, vol. 4, p. 588 (1906) (*Bracon*)
Szépligeti, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 406 (1911) (*Bracon*)

viduus Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 405 (1911) (*Bracon*)

zuluorum Brues — Zululand
Ann. South African Mus., vol. 19, p. 25 (1924)

Cratocnema Szépligeti

Mitt. Zool. Mus., Berlin, vol. 7, p. 184 (1914)
Type: *C. bicolor* Szépligeti

bicolor Szépligeti — Tanganyika Territory
Mitt. Zool. Mus. Berlin, vol. 7, p. 185 (1914)

cephalotus Szépligeti — Spanish Guinea, Camerun
Mitt. Zool. Mus., Berlin, vol. 7, p. 186 (1914)

maculiceps SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 184 (1914)

maculiventris SZEPLIGETI — CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 185 (1914)

nigriventris SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 185 (1914)

pallidipes SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 185 (1914)

polita SZÉPLIGETI — BELGIAN CONGO
Rev. Zool. Africaine, vol. 3, p. 411 (1914)

similis SZÉPLIGETI — CAMERUN, TOGO, SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 185 (1914)

testacea SZÉPLIGETI — CAMERUN, SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 184 (1914)

Braconella SZÉPLIGETI

Ann. Mus. Nat. Hungarici, vol. 4, p. 587 (1906)
ROMAN, Ent. Tidskr., vol. 31, p. 115 (1910)
BRUES, Ann. South African Mus., vol. 19, p. 19 (1924)
Type: *B. major* Szépligeti

fuscipennis SZÉPLIGETI — ABYSSINIA
Ann. Mus. Nat. Hungarici, vol. 11, p. 596 (1913)

major SZÉPLIGETI — EAST AFRICA
Ann. Mus. Nat. Hungarici, vol. 11, p. 587 (1906)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 183 (1914)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 211 (1926)

minor SZÉPLIGETI — EASTERN AFRICA, ZULULAND
Ann. Mus. Nat. Hungarici, vol. 4, p. 587 (1906)
ROMAN, Ent. Tidskr., vol. 31, p. 115 (1910)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 184 (1914)
BRUES, Ann. South African Mus., vol. 19, p. 19 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 211 (1926)

tibialis SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 184 (1914)

Myosoma Brullé

Hist. Nat. Ins. Hymén., vol. 4, p. 450 (1846)

Type: *M. hirtipes* Brullé

luteum Szépligeti — Portuguese East Africa

Ann. Mus. Nat. Hungagici, vol. 11, p. 596 (1913)

Euurobracon Ashmead

Proc. U. S. Nat. Mus., vol. 23, p. 140 (1900)
Ashmead, ibid., vol. 30, p. 197 (1906)
Roman, Ark. Zool., vol. 8, No. 15, p. 45 (1913)
Enderlein, Arch. Naturg., Jahrg 84A (1918), Heft 11, p. 63 (1920)

Type: *E. penetrator* Smith

mandibularis Brues — Natal

Ann. South African Mus., vol. 19, p. 34 (1924)

Exobracon Szépligeti

Termes. Füzetek, vol. 25, p. 45 (1902)

Type: *E. quadriceps* Smith (1860) (*E. impossibilis* Dalla Torre, non *quadriceps* Smith, 1857).

rufus Cameron — Dima, Belgian Congo

Ann. Soc. Ent. Belgique, vol. 56, p. 370 (1912)

Cœlodontus Roman

Zool. Bidrag, Uppsala, vol. 1, p. 246 (1912)

Type: *C. costator* Thunberg

costator Thunberg — Cape Provincce

Roman, Zool. Bidrag, Uppsala, vol. 1, p. 246, pl. 6, fig. 5 (1912)

Iphiaulax Förster

Verh. naturf. Ver. preuss. Rheinlande, vol. 19, p. 243 (1862)

As indicated on a previous page (p. 303) it is at present impossible to separate the numerous genera or subgenera that have been proposed to receive the enormous number of described species in this group. Those to which African species have been referred are listed below. It will be noted that no attempt has been made to propose new names for specific names which are repeated when these "genera" are combined. This has been done as it seems probable that some of these

names will be recognized later as distinguishable genera. Meanwhile any attempt to remove such homonyms as appear below would serve only to add further nomenclatorial difficulties as it would have to be done on a tentative basis.

Antiolcia Enderlein

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 116 (1920)

Type: *A. mitelligera* Enderlein

Bathyaulax Szépligeti

Ann. Mus. Nat. Hungarici, vol. 4, p. 559 (1906)
Roman, Ent. Tidskr., vol. 31, p. 113 (1910)

Type: *B. cyanogaster* Szépligeti

Caliidia Schulz

Zool. Ann., vol. 4, p. 68 (1910)
Szépligeti, Wiss. Ergebn, Kilimandjaro-Meru Exped., vol. 2, p. 35 (1910) (*Eumorpha,* non Hübner 1806, nec Friese, 1899)
Roman, Ent. Tidskr., vol. 31, p. 113 (1910) (*Bathyaulax*)

Type: *C. nigripennis* Szépligeti

Campyloneurus Szépligeti

Termes. Füzetek, vol. 23, p. 102 (1900)
Enderlein, Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 102 (1920)

Type: *C. bicolor* Szépligeti

Cratobracon Cameron

Proc. Zool. Soc., London, p. 226 (1901)
Szépligeti, Ann. Mus. Nat. Hungarici, vol. 4, p. 556 (1906) (*Hybothorax,* preoccupied)
Schulz, Zool. Ann., vol. 4, p. 71 (1911) (*Hybostethus*)
Turner, Ann. Mag. Nat. Hist. (8), vol. 20, p. 242 (1917)
Strand, Intern. Ent. Zeits., vol. 14, p. 174 (1921) (*Hybothoracoïdes*)

Type: *C. ruficeps* Cameron

Cyanopterus Haliday

Ent. Mag., vol. 3, p. 22 (1836)
Thomson, Opusc. Ent., Pt. 18, p. 1787 (1892)

Type: *C. flavator* Fabricius

Eumorpha Szépligeti

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 35 (nec Friese, 1899)
Roman, Ent. Tidskr., vol. 31, p. 113 (1910) (*Bathyaulax*)

Euryacria Enderlein

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 126 (1920)
Type: *E. flavipera* Enderlein

Goniobracon Szépligeti

Ann. Mus. Nat. Hungarici, vol. 4, p. 581 (1906)
Type: *G. perspicax* Szépligeti

Hemibracon Szépligeti

Ann. Mus. Nat. Hungarici, vol. 4, p. 558 (1906)
Type: *H. peruiensis* Szépligeti

Holcobracon Cameron

Arch. Math. Naturvidens., vol. 30, No. 10, p. 19 (1909) (non *Holcobracon* Cameron, 1905)
Type: *H. erythraspis* Cameron

Ipobracon Thomson

Opusc. Ent., pt. 17, p. 1787 (1892)
Szépligeti, Ann. Mus. Nat. Hungarici, vol. 4, p. 549 (1906)
Type: *I. nigrator* Zetterstedt

Macronura Szépligeti

Ann. Mus. Nat. Hungarici, vol. 4, p. 581 (1906)
Type: *M. mirabilis* Szépligeti

Megagonia Szépligeti

Ann. Mus. Nat. Hungarici, vol. 4, p. 582 (1906)
Type: *M. seminigra* Szépligeti

Meganura Szépligeti

Ann. Mus. Nat. Hungarici, vol. 4, p. 552 (1906)
Type *M. major* Szépligeti

Merinotus SZEPLIGETI

Ann. Mus. Nat. Hungarici, vol. 4, p. 553 (1906)
Enderlein, Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 63 (1920)

Type: *M. melanosoma* Brullé
(*æthiopicus* Cameron, *striatus* Szépligeti)

Rhadinobracon SZÉPLIGETI

Ann. Mus. Nat. Hungarici, vol. 4, p. 556 (1906)

Type: *R. trägårdi* Szépligeti

Trachybracon SZÉPLIGETI

Ann. Mus. Nat. Hungarici, vol. 4, p. 552 (1906)

Type: *T. granulatus* Szépligeti

Udamolx ENDERLEIN

Arch. Naturg., Jahrg. 84A (1918), Heft. 11, p. 97 (1920)

Type: *U. gutta* Enderlein

Iphiaulax SENS. LAT.

abdominalis SZÉPLIGETI — CONGO
Ann. Soc. Ent. Belgique, vol. 58, p. 111 (1914) (*Goniobracon*)

afer SZÉPLIGETI — SIERRA LEONE
Ann. Mus. Nat. Hungarici, vol. 3, p. 29 (1905) (*Iphiaulax*)

africanus DALLA TORRE — CAPE PROVINCE
Cat. Hymen., vol. 4, p. 257 (1898)
HOLMGREN, Eugenies Resa, In. vol. 2, p. 424 (1868) (*Bracon melanopus*, nec Brullé, 1846)

agnata KOHL. — SOUTHERN ARABIA
Ergebn, Exped. Südarabien, Hymen., p. 120 (1906) (*Iphiaulax*)

alluaudi SZÉPLIGETI — KILIMANDJARO
Rés. Sci. Voyage Alluaud, p. 172 (1914) (*Iphiaulax*)

amorosus KOHL — SOKOTRA
Denkschr. Akad. Wiss Wien, vol. 71, p. 291 (1907) (*Bracon*)

annelatus SZÉPLIGETI — CAMERUN, KIBOMBO
Ark. Zool., vol. 2, No. 14, p. 8 (1905)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 406 (1914) (*Ipobracon*)

annulicornis SZÉPLIGETI — CAMERUN
Ark. Zool., vol. 2, No. 4, p. 8 (1905)

annulitarsis CAMERON EASTERN AND SOUTHEASTERN AFRICA
Arch. Math. Naturvidens., vol. 30, No. 10, p. 8 (1909)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 179 (1914)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 226 (1926)

apicalis SZÉPLIGETI ERYTHREA, CAPE PROVINCE
Ann. Mus. Nat. Hungarici, vol. 11, p. 595 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 178 (1914) (*Iphiaulax*)

apicalis SZÉPLIGETI TANGANYIKA TERRITORY
Voy. Rothschild, E. Afr., Anim. Art., Pt. 2, p. 904 (1922) (*Merinotus*)

appelatrix CAMERON CAPE PROVINCE
Arch. Math. Naturvidens., vol. 30, No. 10, p. 13 (1909)

ardens WALKER EGYPT
List. Hymen. Egypt. p. 4 (1871) (*Bracon*)

areolatus SZÉPLIGETI ABYSSINIA, EAST AND SOUTH AFRICA
Ann. Mus. Nat. Hungarici, vol. 11, p. 593 (1913) (*Goniobracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 167 (1914) (*Goniobracon*)

aschantianus Szepligeti EQUATORIAL AFRICA
Termes. Füzetek, vol. 24, p. 364 (1901)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 401 (1911) (*Ipobracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 172 (1914) (*Ipobracon*)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 141 (1915) (*Ipobracon*)

atricauda ENDERLEIN NATAL
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 97 (1920) (*Udamolx*)

atriceps KRIECHBAUMER CONGO
Berliner Ent. Zeits., vol. 39, p. 55 (1894)

atripennis SZÉPLIGETI SOMALILAND
Ann. Mus. Nat. Hungarici, vol. 4, p. 553 (1906) (*Merinotus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 165 (1914) (*Merinotus*)

atripennis SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 168 (1914) (*Goniobracon*)

aurora BRUES TRANSVAAL
Ann. South African Mus., vol. 19, p. 48 (1924)

avunculus KOHL SOUTHERN ARABIA
Denkschr. Akad. Wiss., Wien, vol. 71, p. 281 (1907) (*Vipio*)

basalis SZÉPLIGETI MADONA
Rev. Zool. Africaine, vol. 3, p. 408 (1914) (*Bathyaulax*)

basalis SZÉPLIGETI MOZAMBIQUE
Ann. Mus. Nat. Hungarici, vol. 4, p. 560 (1906) (*Camplyoneurus*)

basalis SZÉPLIGETI USAMBARA
Mitt. Zool. Mus., Berlin, vol. 7, p. 165 (1914) (*Merinotus*)

basiornatus CAMERON NATAL, CAPE PROVINCE
Arch. Naturvidens., vol. 30, No. 10, p. 17 (1909)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 230 (1926)

bellona BRUES RHODESIA, NATAL, TRANSVAAL
Ann. South African Mus., vol. 19, p. 52 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 219 (1926)

bequaerti SZÉPLIGETI BELGIAN CONGO
Rev. Zool. Africaine, vol. 3, p. 410 (1914)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 147 (1915) (*Iphiaulax*)

bicolor Brullé SOUTH AND EAST AFRICA
Hist. Nat. Ins. Hymén., vol. 4, p. 412, pl. 43, fig. 3 (1846) (*Bracon*)
SCHULTESS-SCHINDLER, Bull. Soc. Vaudois, vol. 35, p. 250 (1899) (*Vipio*)
CAMERON, Rec. Albany Mus., Grahamstown, vol. 1, p. 155 (1905)
CAMERON, Arch. Math. Naturvidens, vol. 30, No. 10, p. 14 (1909) (*strenuus*)
BRUES, Ann. South African Mus., vol. 19, p. 61 (1924)

bicolor SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 4, p. 559 (1906) (*Bathyaulax*)

bifasciatus SZÉPLIGETI WESTERN EQUATORIAL AFRICA
Ann. Mus. Nat. Hungarici, vol. 3, p. 28 (1905)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 176 (1914) (*Ipobracon*)

bipunctipennis BRUES BELGIAN CONGO
Proc. American Acad. Arts Sci., vol. 61, p. 214 (1926)

bisignatus Szépligeti WESTERN EQUATORIAL AFRICA
Ann. Mus. Nat. Hungarici, vol. 3, p. 29 (1905)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 176 (1914) (*Ipobracon*)

bohemani Holmgren EASTERN AND SOUTH AFRICA
Eugenies Resa, Ins., vol. 2, p. 423 (1868) (*Bracon*)
Szépligeti, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 32 (1910) (*sjöstedti*, p.p.)
Roman, Ent. Tidskr., vol. 31, p. 128 (1910)

brevicaudis Szépligeti SOMALILAND
Mitt. Zool. Mus., Berlin, vol. 7, p. 166 (1914) (*Megagonia*)

bucephalus Brues NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 212 (1926)

callosus Szépligeti BRITISH SOUTHWEST AFRICA
Beitr. Landf. Südwestafrikas, vol. 1, p. 188 (1918)

calopterus Szépligeti TANGANYIKA TERRITORY
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 33 (1910) (*Iphiaulax*)
Roman, Ent. Tidskr., vol. 31, p. 128 (1910) (*Goniobracon*)

camerunicus Strand CAMERUN
Mitt. Zool. Mus., Berlin, vol. 5, p. 485 (1911) (var. of *neger* Szépligeti)

camerunus Szépligeti CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 170 (1914) (*Campyloneurus*)

camerunus Szépligeti NORTH CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 174 (1914) (*Ipobracon*)

capensis Cameron EQUATORIAL, EAST AND SOUTHEAST AFRICA
Rec. Albany Mus., Grahamstown, vol. 1, p. 149 (1905)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 164 (1914) (*Merinotus*)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 405 (1914) (*Merinotus*)
Brues, Ann. South African Mus., vol. 19, p. 63 (1924)

caracticus Brues NATAL
Proc. American Acad. Arts Sci., vol. 60, p. 224 (1926)

caudatus Szépligeti SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 192 (1914) (*Caliidia*)

caudatus SZÉPLIGETI — TANGANYIKA, NYASALAND

Wiss. Ergebnisse deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 401 (1911) (*Ipobracon*)

SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 175 (1914) (*Ipobracon*)

caudatus SZÉPLIGETI — SPANISH GUINEA

Mitt. Zool. Mus., Berlin, vol. 7, p. 163 (1914) (*Merinotus*)

cephalotus SZÉPLIGETI — TANGANYIKA TERRITORY

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 33 (1910) (*Iphiaulax*)

BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 230 (1926)

clanes CAMERON — CAPE PROVINCE

Rec. Albany Mus., Grahamstown, vol. 1, p. 151 (1905)

coccineus Brullé — EQUATORIAL AND SOUTH AFRICA, MADAGASCAR

Hist. Nat. Ins. Hymén., vol. 4, p. 428 (1846) (*Bracon*)

SCHULTESS-SCHINDLER, Bull. Soc. Vaudois, vol. 35, p. 250 (1899) (*Vipio*)

CAMERON, Ann. South African Mus., vol. 5, p. 49, 52 (1905)

SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 385 (1906)

CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 19 (1909)

SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 34 (1910)

SZÉPLIGETI, Wiss. Ergebn. deutsch Zentral-Afrika Exped. 1907–08, vol. 3, p. 403 (1911)

CAMERON, Ann. Soc. Ent. Belgique, vol. 56, p. 364 (1912)

SZÉPLIGETI Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 422 (1913)

SZÉPLIGETI, Ent. Mitt., vol. 2, p. 384 (1913)

SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 182 (1914)

SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 410 (1914)

SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 171 (1914)

SZÉPLIGETI, Ergebn 2ten. deutsch. Zent.-Afrika Exped., vol. 1, p. 146 (1915)

BRUES, Ann. South African Mus., vol. 19, p. 64 (1924)

collaris SZÉPLIGETI — SENEGAL

Mitt. Zool. Mus., Berlin, vol. 7, p. 179 (1914)

concolor WALKER — EGYPT

List Hymen. Egypt, p. 4 (1871) (*Bracon*) (non *concolor* Marshall. 1888)

concolor SZÉPLIGETI — TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 4, p. 560 (1906) (*Bathyaulax*) (non *concolor* Walker, nec Marshall)

congoënsis CAMERON — BELGIAN CONGO
Ann. Soc. Ent. Belgique, vol. 56, p. 365 (1912)

congoënsis SZÉPLIGETI — KAPIRI
Rev. Zool. Africaine, vol. 3, p. 407 (1914) (*Merinotus*)

congoënsis SZÉPLIGETI — BUKAMA, BELGIAN CONGO
Rev. Zool. Africaine vol. 3, p. 411 (1914) (*Iphiaulax*)

congruus WALKER — EGYPT
List. Hymen Egypt, p. 4 (1871) (*Bracon*)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 172 (1888) (*Bracon*)

conradti SZÉPLIGETI — CAMERUN
Entom. Mitt., vol. 2, p. 384 (1913)

consultus SZÉPLIGETI — CAMERUN, BELGIAN CONGO
Ark. Zool., vol. 2, No. 14, p. 5 (1905)
ROMAN, Zool. Bidrag., vol. 1, p. 260 (1912) (*insidiator*)

coriaceus SZÉPLIGETI — TANGANYIKA TERRITORY
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 29 (1910) (*Ipobracon*)

crassicornis SZÉPLIGETI — BELGIAN CONGO
Ergebn. 2ten. deutsch. Zent.-Africa Exped., vol. 1, p. 143 (1915) (*Ipobracon*)

cristatulus SZÉPLIGETI — CAMERUN, SPANISH GUINEA
Ark. Zool., vol. 2, No. 14, p. 6 (1905)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 167 (1914) (*Bathyaulax*)

curticaudis SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 181 (1914)

cyanogaster SZÉPLIGETI — CAMERUN, TOGO, CONGO
Termes. Füzetek, vol. 24, p. 363 (1901)
SZÉPLIGETI, Ark. Zool., vol. 2, No. 14, p. 4 (1905)
BINGHAM, Trans. Zool. Soc. London, vol. 19, p. 179 (1909) (*rufithorax*)
ROMAN, Ent. Tidskr., vol. 31, p. 144 (1910) (*Bathyaulax*)

SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Africa Exped., vol. 3, p. 398 (1911) (*Bathyaulax*)
SZÉPLIGETI, Entom. Mitt., vol. 3, p. 384 (1913) (*Bathyaulax*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 409 (1914) (*Bathyaulax*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 167 (1914) (*Goniobracon*)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 110 (1914) (*Bathyaulax*)
SZÉPLIGETI, Rés. Sci., Voyage Alluaud, p. 171 (1914) (*Bathyaulax*)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 145 (1915) (*Goniobracon*)

decemmaculatus SZÉPLIGETI — TANGANYIKA, RHODESIA
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 404 (1911)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 230 (1926)

decorus CAMERON — CAPE PROVINCE, NATAL
Ann. South African Mus., vol. 5, p. 50 (1906)
BRUES, ibid, vol. 19, p. 62 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 219 (1926)

delagoënsis CAMERON — DELAGOA BAY
Arch. Math. Naturvidens., vol. 30, No. 10, p. 16 (1909)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 409 (1914) (*Goniobracon*)

deliberator SZÉPLIGETI — CAMERUN, NYASALAND
Ark. Zool., vol. 2, No. 14, p. 7 (1905)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 401 (1911) (*Ipobracon*)

denticornis ENDERLEIN — CAMERUN
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 123 (1920) (*Goniobracon*)

denunciator FABRICIUS — CENTRAL AFRICA
Spec. Ins., vol. 1, p. 428 (1781) (*Ichneumon*)
FABRICIUS, Syst. Piez., p. 107 (1804) (*Bracon*)

determinatus WALKER — EGYPT, SUDAN
List. Hymen. Egypt, p. 4 (1871) (Bracon)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 172 (1888) (*Bracon*)

diana BRUES — SOUTHERN RHODESIA
Ann. South African Mus., vol. 19, p. 49 (1924)

didymus BRULLÉ — EQUATORIAL AFRICA, RÉUNION, MAURITIUS, MADAGASCAR

Hist. Nat. Ins. Hymén., vol. 4, p. 425 (1846) (*Bracon*)
ROMAN, Ent. Tidskr., vol. 31, p. 129 (1910)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 421 (1913) (*Iphiaulax*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 179 (1914) (*Iphiaulax*)

difficilis SZÉPLIGETI — TOGO, CAMERUN, TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 182 (1914)

dimaënsis CAMERON — DIMA, BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 366 (1912)

distinctus Lucas — ALGERIA

Expl. Sci. Algérie, Zool., vol. 3, p. 335 (1846) (*Bracon*)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 138 (1888) (*Bracon*)
MARSHALL, ibid., vol. 5bis, p 42 (1897) (*Bracambus*)
SCHMIEDEKNECHT, Illustr. Wochenschr. Ent., vol. 1, p. 512 (1896) (*Bracon*)

dodsi CAMERON — EASTERN AND SOUTH AFRICA

Ann. South African Mus., vol. 5, p. 51 (1906)
BRUES, ibid., vol. 19, p. 63 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 219 (1926)

dorsalis SZÉPLIGETI — WESTERN EQUATORIAL AFRICA

Mitt. Zool. Mus., Berlin, vol. 7, p. 177 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 409 (1914)
SZÉPLIGETI, Ergebn. 2ten. deutsch. Zent.-Afrika Exped., vol. 1, p. 146 (1915) (*Iphiaulax*)

dubiosus SZÉPLIGETI — BELGIAN CONGO, TANGANYIKA

Wiss. Ergebn. deutsch Zentral-Afrika Exped. 1907–08, vol. 3, p. 397 (1911) (*Bathyaulax*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 409 (1914) (*Bathyaulax*)

dubiosus SZÉPLIGETI — TANGANYIKA TERRITORY

Rés. Sci. Voyage Alluaud, p. 173 (1914) (*Iphiaulax*)

duodecimfasciatus CAMERON — RHODESIA, CAPE PROVINCE

Rec. Albany Mus., Grahamstown, vol. 1, p. 154 (1905)
CAMERON, Ann. South African Mus., vol. 5, p. 55 (1906)

Brues, ibid., vol. 19, p. 63 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 221 (1926)

durbanensis Cameron — Natal
Ann. South African Mus., vol. 5, p. 43 (1906)
Cameron, Ann. Transvaal Mus., vol. 2, p. 192 (1911) (*pretoriaënsis*)

duvivieri Szépligeti — Congo
Ann. Soc. Ent. Belgique, vol. 58, p. 112 (1914) (*Iphiaulax*)

elegans Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 399 (1911) (*Macronura*)

elegans Szépligeti — Camerun
Mitt. Zool. Mus., Berlin, vol. 7, p. 170 (1914) (*Campyloneurus*)

elegans Szépligeti — Togo
Mitt. Zool. Mus., Berlin, vol. 7, p. 177 (1914) (*Iphiaulax*)

erlangeri Szépligeti — Somaliland
Mitt. Zool. Mus., Berlin, vol. 7, p. 172 (1914) (*Ipobracon*)

erythræana Szépligeti — Erythrea
Ann. Mus. Nat. Hungarici, vol. 11, p. 595 (1913)

erythraspis Cameron — Southwest Africa
Arch. Math. Naturvidens., vol. 30, No. 10, p. 20 (1909) (*Holcobracon*)

excisus Szépligeti — Delagoa Bay
Ann. Soc. Ent. Belgique, vol. 58, p. 112 (1914) (*Iphiaulax*)

extricator Nees — Algeria (Europe)
Hymen. Ichneum. affin. Monogr., vol. 1, p. 96 (1834) (*Bracon*)
Schmiedeknecht, Illustr. Wochenschr. Ent., vol. 1, p. 512 (1896) (*Bracon*)
Marshall, Hymén. Europe et Algérie, vol. 5bis, p. 42 (1897) (*Bracambus*)

facialis Szépligeti — Belgian Congo
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 141 (1915) (*Ipobracon*)

facialis Szépligeti — Tanganyika Terr., Zanzibar
Ann. Mus. Nat. Hungarici, vol. 11, p. 594 (1913)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 177 (1914) (*Iphiaulax*)

fastidiator FABRICIUS — NORTH TO SOUTH AFRICA

Spec. Ins., p. 428 (1781) (*Ichneumon*)
Fabricius, Syst. Piez., p. 105 (1804) (*Bracon*)
Walker, List Hymen. Egypt. p. 3, (1871) (*Bracon*)
Ritsema. Tijdschr. v. Ent., vol. 17, p. 179, pl. 11, fig. 1 (1874) (*Bracon corallinus*)
Marshall, Hymén. Europe et Algérie, vol. 4, p. 78 (1888)
Cameron, Ann. Soc. Ent. Belgique, vol. 56, p. 364 (1912) (*Iphiaulax corallinus*)
Turner, Ann. Mag. Nat. Hist. (8), vol. 20, p. 242 (1917)

fenestratus SZÉPLIGETI — TANGANYIKA TERRITORY

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 401 (1911) (*Ipobracon*)

fenestrellus BRUES, nom. nov. — NIGERIA

Brues, Ann. South African Mus., vol. 19, p. 78 (1924) (*Mesobracon fenestratus*, non *Iphiaulax fenestratus* Szépligeti)

filicaudis SZÉPLIGETI — BELGIAN CONGO, EAST AFRICA

Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 397 (1911) (*Rhadinobracon*)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 141 (1915) (*Merinotus*)

filicaudis SZÉPLIGETI — WESTERN EQUATORIAL AFRICA

Mitt. Zool. Mus., Berlin, vol. 7, p. 171 (1914) (*Ipobracon*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 406 (1914) (*Ipobracon*)

flagellaris SZÉPLIGETI — SPANISH GUINEA

Mitt. Zool. Mus., Berlin, vol. 7, p. 183 (1914) (*Cyanopterus*)

flavator FABRICIUS — ALGERIA (Europe)

Entom. Syst., vol. 2, p. 161 (1793) (*Ichneumon*)
NEES, Hymen. Ichneum. affin. Monogr., vol. 1, p. 98 (1834) (*Bracon*)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 42 (1897) (*Bracambus*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 585 (1906) (*Cyanopterus*)
ROMAN, Ent. Tidskr., vol. 31, p. 121 (1910) (*Cyanopterus*)

flaviceps SZÉPLIGETI — TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 175 (1914) (*Ipobracon*)

flaviceps SZÉPLIGETI — SPANISH GUINEA, BELGIAN CONGO

Ergebn. 2ten. Zent-Afrika Exped., vol. 1, p. 141 (1915) (*Merinotus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 163 (1914) (*Merinotus*)

flavipera ENDERLEIN — MADAGASCAR

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 126 (1920) (*Euryacria*)

flavoguttatus GERSTAECKER — MOZAMBIQUE

Mon. Akad. Wiss., Berlin, p. 274 (1858) (*Bracon*)
GERSTAECKER, Reise nach Mossambique, p. 522 (1862) (*Bracon*)

fletcheri CAMERON — PORT SUDAN, RED SEA

Trans. Linn. Soc., London (2), vol. 12, p. 81 (1907)

formasinii KRIECHBAUMER — MOZAMBIQUE

Mem. Accad. Bologna, (5), vol. 4, p. 154 (1894) (*Bracon*)

foveiventris ROMAN — MADAGASCAR

Ent. Tidskr., vol. 33, p. 246 (1912) (*Ipobracon*)

fülleborni SZÉPLIGETI — TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 177 (1914)

fulvipes SZÉPLIGETI — MADAGASCAR

Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 420 (1913) (*Macronura*)

fulvoater BRUES — RHODESIA

Proc. American Acad. Arts. Sci., vol. 61, p. 215 (1926)

fulvus SZÉPLIGETI — TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 179 (1914)

fuscipennis SZÉPLIGETI — CAMERUN

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 139 (1915) (*Campyloneurus*)

fuscipennis SZÉPLIGETI — EQUATORIAL AFRICA

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 147 (1915) (*Cyanopterus*)
SZÉPLIGETI, Ent. Mitt., vol. 2, p. 385 (1913) (*Cyanopterus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 183 (1914) (*Cyanopterus*)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 113 (1914) (*Cyanopterus*)

fuscitarsis Szépligeti — Western Equatorial Africa

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 34 (1910) (*Iphiaulax*)

Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 182 (1914) (*Iphiaulax*)

Szépligeti, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 146 (1915)

gibbus Brullé — Senegal

Hist. Nat. Ins. Hymen., vol. 4, p. 431 (1846) (*Bracon*)

gracilis Szépligeti — Abyssinia, East Africa

Ann. Mus. Nat. Hungarici, vol. 11, p. 595 (1913) (*Iphiaulax*)

Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 180 (1914) (*Iphiaulax*)

granulatus Szépligeti — Congo

Termes. Füzetek, vol. 24, p. 363 (1901) (*Iphiaulax*)

Szépligeti, Ann. Mus. Nat. Hungarici, vol. 4, p. 552 (1906) (*Trachybracon*)

Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 162 (1914) (*Trachybracon*)

grata Enderlein — Tanganyika Territory

Arch. Naturg., Jahrg. 84A (1918), Heft. 11, p. 117 (1920) (*Antiolcia*)

guineënsis Szépligeti — Camerun, Spanish Guinea

Mitt. Zool. Mus., Berlin, vol. 7, p. 176 (1914) (*Ipobracon*)

guineënsis Szépligeti — Spanish Guinea

Mitt. Zool. Mus. Berlin, vol. 7, p. 180 (1914) (*Iphiaulax*)

gutta Enderlein — Natal

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 122 (1920) (*Goniobracon*)

gutta Enderlein — Natal

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 97 (1920) (*Udamolx*)

habesiensis Szépligeti — Somaliland, Erythrea

Ann. Mus. Nat. Hungarici, vol. 11, p. 595 (1913)

Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 178 (1914)

hæmatostigma Kriechbaumer — Gabun

Berliner Ent. Zeits., vol. 39, p. 56 (1894)

hastator Fabricius — Barbarie

Syst. Piez., p. 104 (1804) (*Bracon*)

Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 160 (1888) (*Bracon*)

havilandi CAMERON KATANGA; SOUTH AFRICA

Ann. South African Mus., vol. 5, p. 42 (1906)
CAMERON, Ann. Transvaal Mus., vol. 2, p. 192 (1911)
BRUES, Ann. South African Mus., vol. 19, p. 62 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 221 (1926)

havilandi, var. **rosa** CAMERON SOUTHEAST AND SOUTH AFRICA

Arch. Math. Naturvidens., vol. 30, No. 10, p. 11 (1909) (*rosa*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 164 (1914) (*Merinotus rosa*)
BRUES, Ann. South African Mus., vol. 19, p. 62 (1924)

helvimacula ENDERLEIN ERITREA

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 123 (1920) (*Goniobracon*)

hemixanthopterus SZÉPLIGETI EAST CENTRAL SOUTH AFRICA

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 404 (1911)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 177 (1914)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 172 (1914)

hemixanthus SZÉPLIGETI EAST AFRICA

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 31 (1910) (*Ipobracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 176 (1914) (*Ipobracon*)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 171 (1914) (*Ipobracon*)

hesper BRUES NATAL

Ann. South African Mus., vol. 19, p. 45 (1924)

hirticeps CAMERON CAPE PROVINCE

Arch. Math. Naturvidens., vol. 30, No. 10, p. 12 (1909)

hirtipes SZÉPLIGETI CAMERUN

Mitt. Zool. Mus., Berlin, vol. 7, p. 170 (1914) (*Campyloneurus*)

impostor SCOPOLI MOROCCO (Europe)

Entom. Carn., p. 287 (1763) (*Ichneumon*)
NEES, Hymen. Ichneum. affin. Monogr., vol. 1, p. 399 (1834) (*Bracon*)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 80 (1888) (*Bracon*)
SCHMIEDEKNECHT, Illustr. Wochenschr. Ent., vol. 1, p. 512 (1896) (*Vipio*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 584 (1906)

impressus SZÉPLIGETI TANGANYIKA TERRITORY

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 30 (1910) (*Ipobracon*)
SZÉPLIGETI, Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 401 (1911) (*Ipobracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 174 (1914) (*Ipobracon*)
ROMAN, Ent. Tidskr., vol. 31, p. 112 (1910) (*Atanycolus*)

inanitus CAMERON DELAGOA BAY

Arch. Math. Naturvidens., vol. 30, No. 10, p. 15 (1909)

incisus BRULLÉ RHODESIA, SOUTH AFRICA

Hist. Nat. Ins. Hymén, vol. 4, p. 427 (1846) (*Bracon*)
CAMERON, Ann. South African Mus., vol. 5, p. 47 (1906)
BRUES, ibid., vol. 19, p. 64 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 228 (1926)

incompositus SZÉPLIGETI NORTH CAMERUN

Mitt. Zool. Mus., Berlin, vol. 7, p. 173 (1914) (*Ipobracon*)

insidiator FABRICIUS WESTERN EQUATORIAL AFRICA

Spec. Ins., vol. 1, p. 249 (1781) (*Ichneumon*)
FABRICIUS, Syst. Piez., p. 108 (1804) (*Bracon*)
SZÉPLIGETI, Ark. Zool., vol. 4, No. 14, p. 6 (1905) (*speciosissimus*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 559 (1906) (*speciosissimus*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 3, p. 31 (1905) (*speciosissimus*)
ROMAN, Zool. Bidrag, vol. 1, p. 260 (1912)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 166 (1914) (*Megagonia*)
SZÉPLIGETI, ibid., vol. 7, p. 171 (1914) (*Ipobracon speciosissimus*)
SZÉPLIGETI, Ergebn. 2ten. Zent-Afrika Exped., vol. 1, p. 144 (1915) (*Megagonia*)
TURNER, Ann. Mag. Nat. Hist. (8), vol. 20, p. 242 (1917) (*Ipobracon*)

iphigenia BRUES TRANSVAAL

Ann. South African Mus., vol. 19, p. 55 (1924)

iris BRUES ZULULAND

Ann. South African Mus., vol. 19, p. 47 (1924)

jeanneli SZÉPLIGETI BELGIAN CONGO, UGANDA, KENYA COLONY
Rés. Sci. Voyage Alluaud, p. 173 (1914) (*Iphiaulax*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 409 (1914) (*Iphiaulax*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 225 (1926)

jocosoides BUYSSON TRANSVAAL
Ann. Soc. Ent. France, vol. 46, p. 353 (1897) (*Bracon*)

jocosus GERSTAECKER MOZAMBIQUE
Mon. Akad. Wiss. Berlin, p. 264 (1858) (*Bracon*)
GERSTAECKER, Reise nach Mossambique, p. 523 (1862) (*Bracon*)

juno BRUES TRANSVAAL
Ann. South Africa Mus., vol. 19, p. 53 (1924)

kersteni GERSTAECKER ZANZIBAR, SOKÓTRA
Arch, Naturg., Jahrg. 37, p. 356 (1871) (*Bracon*)
GERSTAECKER, Decken, Reise in Ostafrika, Gliederthiere, p. 631 (1873) (*Bracon*)
KIRBY, Forbes, Nat. Hist. Sokótra, Ins. Hymen, p. 236 (1903)

kolleri CAMERON DIMA, BELGIAN CONGO
Ann. Soc. Ent. Belgique, vol. 56, p. 366 (1912)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 219 (1926)

krebsii Cameron CAPE PROVINCE
Arch. Math. Naturvidens., vol. 30, No. 10, p. 18 (1909)
BRUES, Ann. South African Mus., vol. 19, p. 63 (1924)

læviusculus SZÉPLIGETI MADAGASCAR
Ann. Mus. Nat. Hungarici, vol. 4, p. 585 (1906)

læviventris ENDERLEIN MADAGASCAR
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 126 (1920) (*Bathyaulax*)

lanceolatus SZÉPLIGETI CAPE PROVINCE
Mitt. Zool. Mus., Berlin, vol. 7, p. 178 (1914)

latiangulata ENDERLEIN MADAGASCAR
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 125 (1920) (*Bathyaulax*)

lativentris CAMERON TRANSVAAL, NATAL
Ann. South African Mus., vol. 5, p. 51 (1906)
BRUES, ibid., vol. 19, p. 63 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 229 (1926)

leucogaster CAMERON — DELAGOA BAY
Arch. Math. Naturvidens., vol. 30, No. 10, p. 8 (1909)

liogaster SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 169 (1914) (*Campyloneurus*)

litura Brullé — SOUTH AFRICA
Hist. Nat. Ins. Hymen. vol. 4, p. 415 (1846) (*Bracon*)

longicornis SZÉPLIGETI — CAMERUN
Ann. Mus. Nat. Hungarici, vol. 3, p. 32 (1905)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 182 (1914)

longicornis SZÉPLIGETI — EASTERN EQUATORIAL AFRICA
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 401 (1911) (*Ipobracon*)

longicoxis CAMERON — NATAL
Ann. South African Mus., vol. 5, p. 42 (1906)

lucidus SZÉPLIGETI — BELGIAN CONGO, TANGANYIKA, NYASALAND
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 398 (1911) (*Hemibracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 169 (1914) (*Goniobracon*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 221 (1926)

lucidus SZÉPLIGETI — MADAGASCAR
Wiss. Ergebn., Reise Voeltzkow, vol. 3, p. 421 (1913) (*Iphiaulax*)

lucina BRUES — SOUTHERN RHODESIA
Ann. South African Mus., vol. 19, p. 54 (1924)

lugens BRULLÉ — ZULULAND, NATAL, CAPE PROVINCE
Hist. Nat. Ins. Hymén, vol. 4, p. 414 (1846) (*Bracon*)
HOLMGREN, Eugenies Resa, Ins. vol. 2, p. 426 (1868) (*Bracon victorinii*)
CAMERON, Arch. Math. Naturvidens, vol. 30, No. 10, p. 4 (1909) (*Ipobracon*)
BRUES, Ann. South African Mus., vol. 19, p. 61 (1924)

lukombensis CAMERON — LUKOMBE, BELGIAN CONGO
Ann. Soc. Ent. Belgique, vol. 56, p. 363 (1912)
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 144 (1915) (*Megagonia*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 166 (1914) (*Megagonia*)

maculiceps Szépligeti — Spanish Guinea
Mitt. Zool. Mus. Berlin, vol. 7, p. 170 (1914) (*Campyloneurus*)

maculifrons Ritsema — South Africa
Tijdschr. v. Ent., vol. 17, p. 177 (1874) (*Bracon*)
Brues, Ann. South African Mus., vol. 19, p. 63 (1924)

maculipennis Szépligeti — Somaliland, Tanganyika Terr.
Mitt. Zool. Mus., Berlin, vol. 7, p. 162 (1914) (*Trachybracon*)

madagascariensis Szépligeti — Madagascar
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 421 (1913) (*Iphiaulax*)

magnificus, vide *Plaxopsis magnificus*

martinii Gribodo — East and South Africa
Ann. Mus. Civ. Genova, vol. 14, p. 346 (1879) (*Bracon*)
Cameron, Ann. South African Mus., vol. 5, p. 57 (1906) (*robustus*)
Cameron, Arch. Math. Naturvidens., vol. 30, No. 10, p. 26 (1909) (*Goniobracon robustus*)
Szépligeti, Kilimandjaro-Meru Exped., vol. 2, p. 32 (1910) (*Goniobracon robustus*)
Schulz, Zool. Ann., vol. 4, p. 71 (1911)
Szépligeti, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 402 (1911) (*Goniobracon robustus*)
Szépligeti, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 421 (1913) (*Goniobracon robustus*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 167 (1914) (*Goniobracon robustus*)
Szépligeti, Ann. Soc. Ent. Belgique, vol. 58, p. 111 (1914) (*Goniobracon robustus*)
Szépligeti, Rés. Sci., Voyage Alluaud, p. 171 (1914) (*Goniobracon robustus*)
Szépligeti, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 145 (1915) (*Goniobracon robustus*)
Brues, Ann. South African Mus., vol. 19, p. 61 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 223 (1926)

maximus Szépligeti — Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 173 (1914) (*Ipobracon*)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 406 (1914) (*Ipobracon*)

mediator Cameron — Transvaal
Ann. South African Mus., vol. 5, p. 46 (1906)

megacerus Szépligeti — Tanganyika Territory

Mitt. Zool. Mus., Berlin, vol. 7, p. 182 (1914)

meganura Szépligeti — Africa

Mitt. Zool. Mus., Berlin, vol. 7, p. 164 (1914) (*Merinotus*)

melanarius Walker — Egypt

List Hymen. Egypt, p. 3 (1871) (*Bracon*)

melanopus Holmgren — Cape Province

Eugenies Resa, Ins., vol. 2, p. 424 (1868) (*Bracon*)

melanosoma Brullé — Tanganyika to Cape Province

Hist. Nat. Ins. Hymén, vol. 4, p. 450 (1846) (*Vipio*)
Cameron, Rec. Albany Mus., Grahamstown, vol. 1, p. 153 (1905) (*æthiopicus*)
Cameron, Ann. South African Mus., vol. 5, p. 41 (1906) (*æthiopicus*)
Szépligeti, Ann. Mus. Nat. Hungarici, vol. 4, p. 554 (1906) (*Merinotus striatus*)
Roman, Ent. Tidskr., vol. 31, p. 131 (1910) (*Merinotus*)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 405 (1914) (*Merinotus striatus*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 165 (1914) (*Merinotus striatus*)
Brues, Ann. South African Mus., vol. 19, p. 61 (1924) (*æthiopicus*)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 221 (1926)

meridionalis Cameron — Cape Province

Ann. South African Mus., vol. 5, p. 45 (1906)

microphthalmus Brues — Uganda

Proc. American Acad. Arts Sci., vol. 61, p. 227 (1926)

mimeticus Cameron — Transvaal

Ann. South African Mus., vol. 5, p. 58 (1906)

minerva Brues — Southern Rhodesia

Ann. South African Mus., vol. 19, p. 50 (1924)

minor Szépligeti — Belgian Congo

Ergebn. 2ten Zent.-Afrika Exped., vol. 1, p. 147 (1915) (*Cyanopteris*)

minyas Brues — Zululand, Natal

Ann. South African Mus., vol. 19, p. 43 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 222 (1926)

minyas, var. **kampalensis** BRUES UGANDA
Proc. American Acad. Arts Sci., vol. 61, p. 222 (1926)

mitelligera ENDERLEIN KAMERUN
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 116 (1920) (*Antiolcia*)

mocquerysi SZÉPLIGETI SIERRA LEONE
Ann. Soc. Ent. Belgique, vol. 58, p. 111 (1914) (*Iphiaulax*)

monteiroæ CAMERON DELAGOA BAY
Arch. Math. Naturvidens., vol. 30, No. 10, p. 16 (1909) (*monteiroii*)

nataliensis SZÉPLIGETI SOUTHERN AFRICA
Termes. Füzetek, vol. 24, p. 395 (1901)
CAMERON, Rec. Albany Mus., Grahamstown, vol. 1, p. 150 (1905) (*basimacula*)
CAMERON, Ann. South African Mus., vol. 5, p. 45 (1906) (*basimacula*)
SCHULZ, Spolia Hymenop., p. 140 (1906) (*inacceptus*)
SZÉPLIGETI, Ent. Mitt., vol. 3, p. 384 (1913)
BRUES, Ann. South African Mus., vol. 19, p. 61 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 229 (1926)

neger SZÉPLIGETI GABUN, CAMERUN, BELGIAN CONGO
Termes. Füzetek, vol. 24, p. 365 (1901)
SZÉPLIGETI, Ark. Zool., vol. 2, No. 14, p. 8 (1905)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 3, p. 31 (1905)
SZÉPLIGETI, Wiss. Ergebn, deutsch Zentral-Afrika Exped., vol. 3, p. 400 (1911) (*Ipobracon*)
SZÉPLIGETI, Ent. Mitt., vol. 2, p. 384 (1913) (*Ipobracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 172 (1914) (*Ipobracon*)
SZÉPLIGETI, Ann. Ent. Soc. Belgique, vol. 58, p. 110 (1914) (*Ipobracon*)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 143 (1915) (*Ipobracon*)
ENDERLEIN, Arch. Naturg., Jahrg 84A (1918), Heft. 11, p. 98 (1920) (*Udamolx*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 220 (1926)

niger SZÉPLIGETI SOUTHWEST AFRICA, BÉNI À LESSE
Ann. Mus. Nat. Hungarici, vol. 11, p. 594 (1913) (*Megagonia*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 406 (1914) (*Ipobracon*)

nigricarpus SZÉPLIGETI KIBOMBO
Rev. Zool. Africaine, vol. 3, p. 405 (1914)

nigriceps ENDERLEIN TRANSVAAL
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 125 (1920) (*Bathyaulax*)

nigricoxis SZÉPLIGETI ERYTHREA
Ann. Mus. Nat. Hungarici, vol. 11, p. 594 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 178 (1914)

nigridorsis KRIECHBAUMER CENTRAL AND SOUTH AFRICA
Berliner Ent. Zeits., vol. 39, p. 57 (1894)
BRUES, Ann. South African Mus., vol. 19, p. 63 (1924)

nigrifrons KRIECHBAUMER MOZAMBIQUE
Mem. Accad. Sci. Bologna (5), vol. 4, p. 153 (1894)

nigrimanus SZÉPLIGETI FRENCH CONGO
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 146 (1915) (*Iphiaulax*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 410 (1914) (*Iphiaulax*)

nigripennis SZÉPLIGETI KILIMANDJARO
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 35 (1910) (*Eumorpha*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 192 (1914) (*Caliidia*)

nigripennis SZÉPLIGETI TANGANYIKA TERRITORY
Rés. Sci., Voyage Alluaud, p. 170 (1914) (*Merinotus*)

nigripennis SZÉPLIGETI
Mitt. Zool. Mus., Berlin, vol. 7, p. 165 (1914) (*Rhadinobracon*)

nigripes SZÉPLIGETI SOMALILAND
Mitt. Zool. Mus., Berlin, vol. 7, p. 165 (1914) (*Merinotus*)

nigroscutellaris SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 178 (1914)

novus SZÉPLIGETI CONGO
Termes. Füzetek, vol. 24, p. 396 (1901)

obscuripennis THOMSON TUNIS (Europe)
Opusc. Ent., pt. 17, p. 1803 (1892) (*Bracon*)
SZÉPLIGETI, Mitt. Zool., Mus., Berlin, vol. 7, p. 174 (1914) (*Ipobracon*)

occidentalis SZÉPLIGETI
Mitt. Zool. Mus., Berlin, vol. 7, p. 171 (1914) (*Ipobracon*)

ocellator Fabricius — Tanganyika Territory

Syst. Piez., p. 108 (1804) (*Bracon*)
Szépligeti, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 31 (1910) (*Ipobracon*)

odontoscapus Cameron — Natal, Cape Province

Rec. Albany Mus., Grahamstown, vol. 1, p. 154 (1905)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 228 (1926)

orientalis Szépligeti — Tanganyika Territory

Mitt. Zool. Mus., Berlin, vol. 7, p. 177 (1914)

ornaticollis Cameron — Cape Province

Rec. Albany Mus., Grahamstown, vol. 1, p. 252 (1905)
Cameron, Arch. Math. Naturvidens., vol. 30, No. 10, p. 5 (1909) (*Ipobracon*)

palpator Szépligeti — "Süd-Aethiopien"

Mitt. Zool. Mus., Berlin, vol. 7, p. 176 (1914)

pandora Brues — Southern Africa

Ann. South African Mus., vol. 19, p. 57 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 229 (1926)

pectinatus Enderlein — Transvaal

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 123 (1920) (*Goniobracon*)

pectoralis Szépligeti — Cape Province

Mitt. Zool. Mus., Berlin, vol. 7, p. 181 (1914)

perfectus Szépligeti — Sierra Leone

Ann. Soc. Ent. Belgique, vol. 58, p. 113 (1914) (*Iphiaulax*)

permutans Turner — Nyasaland

Ann. Mag. Nat. Hist. (8), vol. 20, p. 243 (1910)

persimilis Szépligeti — Tanganyika Territory

Ann. Mus. Nat. Hungarici, vol. 4, p. 582 (1906) (*Megagonia*)

persimilis Szépligeti — Tanganyika Territory

Wiss. Ergebn. deutsch Zentral-Afrika Exped. 1907–08, vol. 3, p. 403 (1911) (*Iphiaulax*)

persimilis Szépligeti — Spanish Guinea

Mitt. Zool. Mus., Berlin, vol. 7, p. 170 (1914) (*Campyloneurus*)

persimilis SZÉPLIGETI FRENCH CONGO

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 145 (1915) (*Goniobracon*)

perspicax SZÉPLIGETI SIERRA LEONE

Ann. Mus. Nat. Hungarici, vol. 3, p. 32 (1905)
SZÉPLIGETI, ibid., vol. 4, p. 582 (1906) (*Goniobracon*)

phosphor BRUES ZULULAND, NATAL

Ann. South African Mus., vol. 19, p. 42 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 217 (1926)

phryganator THUNBERG CENTRAL AND SOUTHERN AFRICA

Mem. Akad. St. Petersburg, vol. 8, p. 272 (1822) (*Ichneumon*)
THUNBERG, ibid., vol. 9, p. 342 (1824) (*Ichneumon*)
BRULLÉ, Hist. Nat. Ins. Hymén., vol. 4, p. 414 (1846) (*Bracon luctuosus*)
CAMERON, Arch. Math. Naturvidens., vol. 3, No. 10, p. 5 (1909) (*Ipobracon luctuosus*)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 31 (1910) (*Ipobracon luctuosus*)
ROMAN, Ent. Tidskr., vol. 31, p. 130 (1910) (*Ipobracon*)
ROMAN, Zool. Bidrag, vol. 1, p. 272 (1912) (*Ipobracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 175 (1914) (*Ipobracon luctuosus*)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 171 (1914) (*Ipobracon luctuosus*)

pictipennis SZÉPLIGETI BELGIAN CONGO

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 142 (1915) (*Ipobracon*

pictus BRULLÉ SOUTHERN AFRICA

Hist. Nat. Ins. Hymén., vol. 4, p. 426 (1864) (*Bracon*)
CAMERON, Ann. South African Mus., vol. 5, p. 47, 50 (1906)
CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 19 (1909)
CAMERON, Ann. Transvaal Mus., vol. 2, p. 192 (1911)

plumosus KIRBY WESTERN AND MIDDLE EQUATORIAL AFRICA

Ann. Mag. Nat. Hist., (6), vol. 18, p. 262 (1896) (*Bracon*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 3, p. 30 (1905) (*cristatus*)
SZÉPLIGETI, ibid., vol. 4, p. 559 (1906) (*Bathyaulax cristatus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 167 (1914) (*Bathyaulax*)

SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 111 (1914) (*Bathyaulax*)
SZÉPLIGETI, ibid., t.c., p. 110 (*Bathyaulax cristatus*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 409 (1914) (*Bathyaulax*)
SZÉPLIGETI, Ergebn. 2ten Zent.-Afrika Exped., vol. 1, p. 145 (1915) (*Bathyaulax*)
TURNER, Ann. Mag. Nat. Hist. (8), vol. 20, p. 242 (1917) (*Bathyaulax*)

plurimacula BRULLÉ — CAPE PROVINCE
Hist. Nat. Ins. Hymén., vol. 4, p. 429 (1846) (*Bracon*)
CAMERON, Ann. South African Mus., vol. 5, p. 46 (1906) (*coccineomaculatus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 178 (1914)
TURNER, Ann. Mag. Nat. Hist. (8), vol. 20, p. 243 (1917)
BRUES, Ann. South African Mus., vol. 19, p. 62 (1924)

possessor SZÉPLIGETI — KAMERUN, SPANISH GUINEA
Ark. Zool., vol. 2, No. 14, p. 8 (1905)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 172 (1914) (*Ipobracon*)
ENDERLEIN, Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 98 (1920) (*Udamolx*)

pravus SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 179 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 409 (1914)

preussi SZÉPLIGETI — CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 179 (1914)

proserpina BRUES — SOUTHERN AFRICA
Ann. South African Mus., vol. 19, p. 44 (1924)

pulchricaudis SZÉPLIGETI — SIERRA LEONE, SPANISH GUINEA
Ann. Mus. Nat. Hungarici, vol. 3, p. 30 (1905)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 167 (1914) (*Bathyaulax*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 408 (1914) (var. of *Bathyaulax cristatus*)

pulchripennis SZÉPLIGETI — KILIMANDJARO
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 27 (1910) (*Atanycolus*)
ROMAN, Ent. Tidskr., vol. 31, p. 131 (1910) (*Merinotus*)

quadricolor SZÉPLIGETI AMANI, EAST AFRICA
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., 1907–08, vol. 3, p. 400 (1911) (*Macronura*)

radiator BRUES NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 216 (1926)

resolutus CAMERON CAPE PROVINCE
Arch. Math. Naturvidens., vol. 30, No. 10, p. 10 (1909)

rhadamanthus BRUES CAPE PROVINCE
Ann. South African Mus., vol. 19, p. 59 (1924)

rhamnura SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 162 (1914) (*Merinotus*)

rhodesianus CAMERON SOUTHERN RHODESIA
Ann. South African Mus., vol. 5, p. 54 (1906)

ribesiferus BUYSSON TRANSVAAL
Ann. Soc. Ent. France, vol. 46, p. 353 (1897) (*Bracon*)

ruber BINGHAM MASHONALAND
Trans. Ent. Soc. London, vol. 23, p. 545 (1902)
BRUES, Ann. South African Mus., vol. 19, p. 62 (1924)

rubiginator THUNBERG CAPE PROVINCE
Mém. Akad. St. Petersburg, vol. 8, p. 260 (1822) (*Ichneumon*)
THUNBERG, idem, vol. 9, p. 309 (1824) (*Ichneumon*)
CAMERON, Ann. South African Mus., vol. 5, p. 44 (1906) (*levissimus*)
ROMAN, Zool. Bidrag, vol. 1, p. 277 (1912) (*Ipobracon*)
BRUES, Ann. South African Mus., vol. 19, p. 61 (1924)

rubrilineatus CAMERON CAPE PROVINCE
Rec. Albany Mus., Grahamstown, vol. 1, p. 151 (1905)
CAMERON, Arch. Math. Naturvidens, vol. 30, No. 10, p. 15 (1909)

rubrinervis CAMERON CAPE PROVINCE
Rec. Albany Mus., Grahamstown, vol. 1, p. 152 (1905)
CAMERON, Ann. South African Mus., vol. 5, p. 47 (1906)

ruficauda ENDERLEIN BRITISH SOUTHWEST AFRICA
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 71 (1920) (*Merinotus*)

rufithorax SZÉPLIGETI
Mitt. Zool. Mus., Berlin, vol. 7, p. 163 (1914) (*Merinotus*)

rufolineatus CAMERON DIMA, BELGIAN CONGO
Ann. Soc. Ent. Belgique, vol. 56, p. 362 (1912)

rufus SZÉPLIGETI KILIMANDJARO
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 29 (1910) (*Campyloneurus*)

rufus SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 4, p. 582 (1906) (*Megagonia*)

rugiventris ENDERLEIN SOUTHERN RHODESIA, TANGANYIKA TERR.
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 124 (1920) (*Bathyaulax*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 220 (1926)

rugosus BRULLÉ CAPE PROVINCE
Hist. Nat. Ins. Hymén., vol. 4, p. 413 (1846) (*Bracon*)

rugosus SZÉPLIGETI SPANISH GUINEA, CONGO, TANGANYIKA TERR.
Mitt. Zool. Mus., Berlin, vol. 7, p. 180 (1914) (*Iphiaulax*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 410 (1914) (*Iphiaulax*)

sanguinator THUNBERG EQUATORIAL AND SOUTHEASTERN AFRICA
Mém. Akad. St. Petersburg, vol. 8, p. 260 (1822) (*Ichneumon*)
GERSTAECKER, Mon. Akad. Wiss. Berlin, p. 264 (1858) (*Bracon flagrator*)
SZÉPLIGETI, Termes, Füzetek, vol. 24, p. 395 (1901) (*flagrator* and *wahlbergi*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 585 (1906) (*flagrator*)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 34 (1910) (*flagrator*)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 403 (1911) (*flagrator*)
ROMAN, Zool. Bidrag, vol. 1, p. 278 (1912)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 422 (1913) (*flagrator*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 410 (1914) (*flagrator*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 181 (1914) (*flagrator*)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 112 (1914) (*flagrator*)
SZÉPLIGETI, Rés. Sci., Voyage Alluaud, p. 172 (1914) (*flagrator*)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 146 (1915) (*flagrator*)

sanguinosus HOLMGREN MAURITIUS
Eugenia Resa, Ins., p. 421 (1868) (*Bracon*)

schröderi SZÉPLIGETI TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 180 (1914)

schubotzi Szépligeti — French Congo

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 142 (1915) (*Ipobracon*)

scoparius Szépligeti — Western Equatorial Africa

Ann. Mus. Nat. Hungarici, vol. 3, p. 31 (1905)

Szépligeti, Rev. Zool. Africaine, vol. 3, p. 408 (1914) (*Bathyaulax*)

Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 167 (1914) (*Bathyaulax*)

Szépligeti, Ann. Soc. Ent. Belgique, vol. 58, p. 111 (1914) (*Bathyaulax*)

Szépligeti, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 145 (1915) (*Bathyaulax*)

scrupulosus Szépligeti — Tanganyika Territory

Mitt. Zool. Mus., Berlin, vol. 7, p. 182 (1914)

sculpturatus Walker — Arabia

List. Hymén. Egypt, p. 3 (1871) (*Bracon*)

Marshall, Spéc. Hymén. Europe Algérie, vol. 4, p. 171 (1888) (*Bracon*)

scutellaris Szépligeti — Mozambique

Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 442 (1913) (*Iphiaulax*)

semiluteus Szépligeti — Nyasaland

Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 404 (1911)

seminiger Szépligeti — Somaliland, Tanganyika Territory

Ann. Mus. Nat. Hungarici, vol. 4, p. 582 (1906) (*Megagonia*)

Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 166 (1914) (*Megagonia*)

Szépligeti, Ann. Soc. Ent. Belgique, vol. 58, p. 111 (1914) (*Megagonia*)

seminiger Szépligeti — Tanganyika Territory

Mitt. Zool. Mus., Berlin, vol. 7, p. 164 (1914) (*Merinotus*)

seminiger Szépligeti — Togo

Mitt. Zool. Mus., Berlin, vol. 7, p. 167 (1914) (*Goniobracon*)

seticornis Szépligeti — Belgian Congo

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 143 (1915) (*Ipobracon*)

setosus Szépligeti — Mozambique

Mitt. Zool. Mus., Berlin, vol. 7, p. 173 (1914) (*Ipobracon*)

sexfasciatus CAMERON BELGIAN CONGO
Ann. Soc. Ent. Belgique, vol. 56, p. 365 (1912)

signatus BRULLÉ EQUATORIAL AND SOUTHERN AFRICA
Hist. Nat. Ins. Hymen., vol. 4, p. 430 (1846) (*Bracon*)
CAMERON, Ann. South African Mus., vol. 5, p. 47 (1906)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 585 (1906)
BRUES, ibid., vol. 19, p. 62 (1924)

similis SZÉPLIGETI SOUTH AFRICA
Ent. Mitt., vol. 3, p. 384 (1913) (*Campyloneurus*)
BRUES, Ann. South African Mus., vol. 19, p. 64 (1924)

simulator SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 181 (1914)

sjöstedtii SZÉPLIGETI TANGANYIKA TERRITORY
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 32 (1910)
ROMAN, Ent. Tidskr., vol. 31, p. 128 (1910)

soleæ CAMERON CAPE PROVINCE
Rec. Albany Mus., Grahamstown, vol. 1, p. 164 (1905)

somaliensis SZÉPLIGETI SOMALILAND
Mitt. Zool. Mus., Berlin, vol. 7, p. 168 (1914) (*Goniobracon*)

spathulatus SZÉPLIGETI WESTERN EQUATORIAL AFRICA
Mitt. Zool. Mus., Berlin, vol. 7, p. 166 (1914) (*Bathyaulax*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 408 (1914) (*Bathyaulax*)

spathuliformis SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 174 (1914) (*Ipobracon*)

speciosus SZÉPLIGETI GABUN
Termes. Füzetek, vol. 24, p. 364 (1901)
ENDERLEIN, Arch, Naturg., Jahrg. 84A (1918), Heft 11, p. 97 (1920) (*Udamolx*)

spilonotus CAMERON SOUTHERN AFRICA
Rec. Albany Mus., Grahamstown, vol. 1, p. 165 (1905)
BRUES, Ann. South African Mus., vol. 19, p. 62 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 228 (1926)

spilopus CAMERON CAPE PROVINCE
Rec. Albany Mus., Grahamstown, vol. 1, p. 241 (1905)

stanleyi CAMERON LEOPOLDVILLE, CONGO
Ann. Soc. Ent. Belgique, vol. 56, p. 368 (1912)

striatus Szépligeti Spanish Guinea, Tanganyika Territory
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 420 (1913) (*Ipobracon*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 176 (1914) (*Ipobracon*)

striolatus Szépligeti Sierra Leone
Mitt. Zool. Mus., Berlin, vol. 7, p. 168 (1914) (*Goniobracon*)

striolatus Szépligeti Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 169 (1914) (*Campyloneurus*)

subtauratus Kriechbaumer Gabun
Berliner Ent. Zeits., vol. 39, p. 57 (1895) (*Bracon*)
Szépligeti, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 33 (1910)

sulphureus Szépligeti South Camerun
Mitt. Zool. Mus., Berlin, vol. 7, p. 175 (1914) (*Ipobracon*)

tacitus Cameron Delagoa Bay
Arch. Math. Naturvidens., vol. 30, No. 10, p. 9 (1909)

tanycerus Cameron Cape Province
Ann. South African Mus., vol. 5, p. 49 (1906)

tegularis Szépligeti Cape Province
Ann. Mus. Nat. Hungarici, vol. 4, p. 585 (1906)
Brues, Ann. South African Mus., vol. 19, p. 62 (1924)

tessmanni Szépligeti Spanish Guinea, Belgian Congo
Mitt. Zool. Mus., Berlin, vol. 7, p. 163 (1914) (*Merinotus*)

tessmanni Szépligeti Equatorial Africa
Mitt. Zool. Mus., Berlin, vol. 7, p. 172 (1914) (*Ipobracon*)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 406 (1914) (*Ipobracon*)

testaceus Szépligeti Belgian Congo
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 143 (1915) (*Ipobracon*)

thisbe Brues Cape Province
Ann. South African Mus., vol. 19, p. 58 (1924)

tigrinus Szépligeti Congo, Tanganyika Territory
Wiss. Ergebn, Kilimandjaro-Meru Exped., vol. 2, p. 33 (1910) (*Iphiaulax*)
Roman, Ent. Tidskr., vol. 31, p. 128 (1910) (*Goniobracon*)
Szépligeti, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 421 (1913) (*Iphiaulax*)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 229 (1926)

tigrinus var. **interruptus** Szépligeti — Tanganyika Territory
Wiss. Ergebn. Kilimandjaro-Meru-Exped., vol. 2, p. 34 (1910) (*Iphiaulax*)

tincticanaliculatus Cameron — Belgian Congo
Ann. Soc. Ent. Belgique, vol. 56, p. 367 (1912)

togoanus nom. nov. — Togo
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 406 (1914) (*Ipobracon togoënsis* Szépligeti, nec *Ipobracon togoënsis* Szépligeti, 1914)

togoënsis Szépligeti — Togo
Mitt. Zool. Mus., Berlin, vol. 7, p. 174 (1914) (*Ipobracon*)

togoënsis Szépligeti — Togo
Mitt. Zool. Mus., Berlin, vol. 7, p. 177 (1914) (*Iphiaulax*)

trägårdi Szépligeti — White Nile
Ark. Zool., vol. 2, No. 14, p. 10 (1904)
Szépligeti, Ann. Mus. Nat. Hungarici, vol. 4, p. 556 (1906) (*Rhadinobracon*)
Szépligeti, ibid., t.c., p. 554 (1906) (*Merinotus bicostatus*)
Roman, Ent. Tidskr., vol. 31, p. 131 (1910) (*Merinotus*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 164 (1914) (*Merinotus bicostatus*)

transiens Szépligeti
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 399 (1911)

transitus Szépligeti — Somaliland, Tanganyika Territory
Ann. Mus. Nat. Hungarici, vol. 11, p. 593 (1913) (*Goniobracon*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 169 (1914) (*Goniobracon*)
Szépligeti, Ann. Soc. Ent. Belgique, vol. 58, p. 111 (1914) (*Goniobracon*)

trichiosomus Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 55 (1906)

tricolor Szépligeti — Kilimandjaro
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 30 (1910) (*Ipobracon*)

tricolor Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 396 (1911) (*Meganura*)

trifasciatus Szépligeti — Camerun, Sierra Leone

Ann. Mus. Nat. Hungarici, vol. 3, p. 31 (1905)
Szépligeti, ibid., vol. 4, p. 562 (1906) (*Ipobracon*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 177 (1914) (*Iphiaulax*)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 410 (1914) (*Iphiaulax*)
Szépligeti, Ergebn. 2ten Zent.-Afrika Exped., vol. 1, p. 146 (*Iphiaulax*)

trimeni Cameron — Eastern and South Africa

Rec. Albany Mus., Grahamstown, vol. 1, p. 240 (1905)
Cameron, Ann. South African Mus., vol. 5, p. 41 (1906) (*xanthopterus*)
Szépligeti, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 31 (1910) (*Ipobracon xanthopterus*)
Brues, Ann. South African Mus., vol. 19, p. 61 (1924) (*xanthopterus*)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 220 (1926)

uelleburgensis Szépligeti — Spanish Guinea

Mitt. Zool. Mus., Berlin, vol. 7, p. 173 (1914) (*Ipobracon*)

unicolor Szépligeti — Equatorial Africa

Ann. Mus. Nat. Hungarici, vol. 11, p. 595 (1913)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 180 (1914)
Szépligeti, Ann. Soc. Ent. Belgique, vol. 58, p. 112 (1914) (*Iphiaulax*)

urinator Fabricius — Egypt, Algeria (Europe)

Suppl. Entom. System., p. 224 (1798) (*Ichneumon*)
Nees, Hymen. Ichneum. affin Monogr., vol. 1, p. 118 (1834) (*Bracon*)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 156 (1888) (*Bracon*)
Schmiedeknecht, Illustr. Wochenschr. Ent., vol. 1, p. 590, 591 (1896) (*Bracon*)

varicollis Cameron — Cape Province

Arch. Math. Naturvidens., vol. 30, No. 10, p. 7 (1909)

variegatus Szépligeti — Madagascar

Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 420 (1913) (*Ipobracon*)

varipalpis Cameron — Transvaal

Ann. South African Mus., vol. 5, p. 48 (1906)
Cameron, Ann. Transvaal Mus., vol. 2, p. 193 (1911)

varipennis SZÉPLIGETI — SOMALILAND
Mitt. Zool. Mus., Berlin, vol. 7, p. 168 (1914) (*Goniobracon*) (nec *Iphiaulax variipennis* Pérez)

varitinctus CAMERON — CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 50 (1906)
BRUES, ibid., vol. 19, p. 62 (1924)

varius BRULLÉ — NUBIA
Hist. Nat. Ins. Hymén, vol. 4, p. 428 (1846) (*Bracon*)

vesta BRUES — TRANSVAAL
Ann. South African Mus., vol. 19, p. 56 (1924)

wahlbergi HOLMGREN — CENTRAL AND SOUTHERN AFRICA
Eugenies Resa, Ins., p. 425 (1868) (*Bracon*)
CAMERON, Ann. South African Mus., vol. 5, p. 47 (1906)
ROMAN, Ent. Tidskr., vol. 31, p. 129 (1910)
SZÉPLIGETI, Ent. Mitt., vol. 2, p. 384 (1913) (*flagrator*)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 422 (1913)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 112 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 181 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 410 (1914)

whitei CAMERON — ZULULAND, TRANSVAAL
Rec. Albany Mus., Grahamstown, vol. 1, p. 165 (1905)
BRUES, Ann. South African Mus., vol. 19, p. 62 (1924)

xanthocarpus CAMERON — CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 41 (1906)

xanthocephalus SZÉPLIGETI — NYASALAND
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 404 (1911)

xanthostomus CAMERON — SOUTHERN AFRICA
Ann. South African Mus., vol. 5, p. 56 (1906)

zanzibaricus SZÉPLIGETI — MOZAMBIQUE, ZANZIBAR
Ann. Mus. Nat. Hungarici, vol. 4, p. 554 (1906) (*Merinotus*)

zanzibaricus var. **australis** ROMAN — CAPE PROVINCE
Ent. Tidskr., vol. 31, p. 132 (1910) (*Merinotus*)

Archibracon SAUSSURE

Grandidier, Hist. Madagascar, vol. 20, Hymén, Pl. 14, fig. 13 (1892)
SZÉPLIGETI, Genera Insect., fasc. 22, p. 48 (1904) (*Pseudobracon*)

ROMAN, Ent. Tidskr., vol. 31, p. 130 (1910) (*Pseudobracon*)
SCHULZ, Zool. Ann., vol. 4, p. 68 (1911)
ENDERLEIN, Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 58, 221 (1920)

Type: A *flaviceps* Brullé

affinis SZÉPLIGETI — TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 192 (1914) (*Pseudobracon*)

cameroni BRUES — NATAL, ZULULAND

Ann. South African Mus., vol. 19, p. 78 (1924)
CAMERON, ibid., vol. 5, p. 73 (1906) (*Exothecus flaviceps*, non *Archibracon flaviceps* Brullé
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 231 (1926)

capensis CAMERON — CAPE PROVINCE

Rec. Albany Mus., Grahamstown, vol. 1, p. 167 (1905)

cognatus SZÉPLIGETI — CAPE PROVINCE

Mitt. Zool. Mus., Berlin, vol. 7 , p. 192 (1914) (*Pseudobracon*)

concolor SZÉPLIGETI — TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 4, p. 596 (1906) (*Pseudobracon*)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 406 (1911) (*Pseudobracon*)

crudelis COQUEREL — MADAGASCAR

Ann. Soc. Ent. France, (3), vol. 4, p. 508 (1856) (*Agathis*)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 114 (1914) (*Pseudobracon*)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 148 (1915) (*Pseudobracon*)

elizabethæ CAMERON — NATAL, CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 72 (1906) (*Exothecus*)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 231 (1926)

fasciatus SZÉPLIGETI — WESTERN EQUATORIAL AFRICA

Mitt. Zool. Mus., Berlin, vol. 7, p. 191 (1914) (*Pseudobracon*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 411 (1914) (*Pseudobracon*)
SZÉPLIGETI, Ergebn. 2ten Zent.-Afrika Exped., vol. 1, p. 148 (1915) (*Pseudobracon*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 231 (1926)

fenestralis SZÉPLIGETI — TANGANYIKA TERRITORY

Wiss. Eregbn deutsch. Zentral-Afrika Exped., 1907–08, vol. 3, p. 406 (1911) (*Pseudobracon*)

SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 193 (1914) (*Pseudobracon*)

flaviceps BRULLÉ — MADAGASCAR

Hist. Nat. Ins. Hymén., vol. 4, p. 410 (1846) (*Bracon*)

SAUSSURE, Grandidier, Hist. Nat. Madagascar, vol. 20, pl. 14, fig. 13 (1892)

SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 423 (1913) (*Pseudobracon flavimanus*)

ENDERLEIN, Arch. Naturg., Jahrg. 84A (1918), Heft 11, p.222 (1920)

flavofasciatus CAMERON — CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 74 (1906) (*Exothecus*)

forticornis CAMERON — TRANSVAAL

Ann. South African Mus., vol. 5, p. 74 (1906) (*Exothecus*)

megacephalus SZÉPLIGETI — SPANISH GUINEA, BELGIAN CONGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 190 (1914) (*Pseudobracon*)

BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 232 (1926)

nigricornis KRIECHBAUMER — SIERRA LEONE

Berliner Ent. Zeits., vol. 39, p. 59 (1894) (*Exothecus*)

szepligetii NOM.NOV. — BELGIAN CONGO, TOGO

SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 114 (1914) (*Pseudobracon nigricornis*, non Kriechbaumer, 1894)

SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 190 (1914) (*Pseudobracon nigricornis*)

nigrifrons KRIECHBAUMER — CONGO

Berliner Ent. Zeits., vol. 39, p. 59 (1894) (*Exothecus*)

nigripennis SZÉPLIGETI — LAGOS

Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 102 (1913) (*Pseudobracon*)

pulchricornis SZÉPLIGETI — BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 58, p. 114 (1914) (*Pseudobracon*)

pulchripennis CAMERON — CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 73 (1906) (*Exothecus*)

BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 231 (1926)

ruficeps Szépligeti — Somaliland

Ann. Ent. Soc. Belgique, vol. 58, p. 114 (1914) (*Pseudobracon*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 190 (1914) (*Pseudobracon*)

schubotzi Szépligeti — Western Equatorial Africa

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 148 (1915) (*Pseudobracon*)
Szépligeti, Ent. Mitt., vol. 2, p. 385 (1913) (*Pseudobracon*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 191 (1914) (*Pseudobracon*)
Szépligeti, Ann. Soc. Ent. Belgique, vol. 58, p. 114 (1914) (*Pseudobracon*)

servillei Brullé — Equatorial and South Africa

Hist. Nat. Ins. Hymén., vol. 4, p. 418 (1846) (*Bracon*)
Szépligeti, Genera Insect., fasc. 22, p. 49 (1904) (*Pseudobracon africanus*)
Cameron, Rec. Albany Mus., Grahamstown, vol. 1, p. 156 (1905) (*Exothecus tibialis*)
Cameron, ibid., t.c., p. 167 (1905) (*Exothecus canaliculatus*)
Cameron, Ann. South African Mus., vol. 5, p. 75 (1906) (*Exothecus canaliculatus*)
Szépligeti, Ann. Mus. Nat. Hungarici, vol. 4, p. 596 (1906) (*Pseudobracon africanus*)
Szépligeti, Ann. Mus. Nat. Hungarici, vol. 6, p. 397 (1908) (*Pseudobracon africanus*)
Cameron, Zeits. Naturwiss., vol. 81, p. 433 (1910) (*Pseudobracon africanus*)
Szépligeti, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 36 (1910) (*Pseudobracon*)
Szépligeti, Ann. Ent. Soc. Belgique, vol. 58, p. 114 (1914) (*Pseudobracon*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 191 (1914) (*Pseudobracon africanus*)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 413 (1914) (*Pseudobracon*)
Szépligeti, Rés. Sci. Voyage Alluaud, p. 175 (1914) (*Pseudobracon*)
Szépligeti, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 148 (1915) (*Pseudobracon*)
Brues, Ann. South African Mus., vol. 19, p. 77 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 231 (1926)

silvestrii Szépligeti — Lagos
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 102 (1913) (*Pseudobracon*)

spilopterus Cameron — Cape Province
Rec. Albany Mus., Grahamstown, vol. 1, p. 166 (1905)

striolatus Szépligeti — Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 191 (1914) (*Pseudobracon*)

voeltzkowi Szépligeti — Madagascar
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 423 (1912) (*Pseudobracon*)

xanthocephalus Szépligeti — Camerun, Belgian Congo
Rev. Zool. Africaine, vol. 3, p. 412 (1914)
Szépligeti, Ent. Mitt., vol. 2, p. 385 (1913)

Plaxopsis Szépligeti

Ark. Zool., vol. 2, No. 14, p. 1 (1905)
Roman, Ent. Tidskr., vol. 31, p. 136 (1910)
Type: *P. sjsötedti* Szépligeti

abyssinica Szépligeti — Abyssinia
Ann. Mus. Nat. Hungarici, vol. 11, p. 592 (1913)

büttneri Szépligeti — Spanish Guinea, Togo, Uganda
Mitt. Zool. Mus., Berlin, vol. 7, p. 159 (1914)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 234 (1926)

fenestralis Szépligeti — Tanganyika Territory
Mitt. Zool. Mus., Berlin, vol. 7, p. 160 (1914)

grandidieri Szépligeti — Madagascar
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 419 (1913)

heymonsi Szépligeti — Tanganyika Territory
Mitt. Zool. Mus., Berlin, vol. 7, p. 159 (1914)

levis Szépligeti — Tanganyika Territory
Mitt. Zool. Mus., Berlin, vol. 7, p. 159 (1914)

liogaster Szépligeti — Tanganyika Territory, Zanzibar
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 419 (1913)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

macropterus Szépligeti — French Congo
Ann. Soc. Ent. Belgique, vol. 58, p. 109 (1914)

maculiceps Szépligeti — Béni à Lesse
Rev. Zool. Africaine, vol. 3, p. 407 (1914)

magnificus Enderlein — Tanganyika Territory
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 77 (1920) (*Ipobracon*)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 232 (1926)

nitidula Brues — Natal
Ann. South African Mus., vol. 19, p. 64 (1924)

persimilis Szépligeti — Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 159 (1914)

pulchricaudis Szépligeti — Camerun
Entom. Mitt., vol. 2, p. 383 (1913)

pulchripennis Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 395 (1911)

roseogaster Brues — Uganda
Proc. American Acad. Arts Sci., vol. 61, p. 233 (1926)

schröderi Szépligeti — Togo, Camerun
Mitt. Zool. Mus., Berlin, vol. 7, p. 160 (1914)

schubotzi Szépligeti — Belgian Congo
Ergebn. 2ten Zent.-Afrika Exped., vol. 1, p. 140 (1915)

schultzei Szépligeti — Spanish Guinea, Belgian Congo
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 140 (1915)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 159 (1914)

sjöstedti Szépligeti — Camerun
Ark. Zool., vol. 2, No. 14, p. 1 (1905)

trifasciatus Szépligeti — Ruwenzori
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 395 (1911)

Chaoilta Cameron

Mem. Manchester Philos. Soc., vol. 43, p. 80 (1899)
Szépligeti, Termes. Füzetek, vol. 23, p. 50 (1900) (*Blastomorpha*)

Type: *C. lamellata* Cameron

amplificata Brues — Zululand
Ann. South African Mus., vol. 19, p. 66 (1924)

Odontoscapus KRIECHBAUMER

Mem. Accad. Sci., Bologna, (5), vol. 4, p. 154 (1894)
SZÉPLIGETI, Termes. Füzetek, vol. 23, p. 49 (1900) (*Platybracon*)
CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 20 (1909) (*Doryctocephalus*)
ROMAN, Ent. Tidskr., vol. 31, p. 135 (1910) (*Platybracon; Campyloneurus*)

Type: *O. varistigma* Kriechbaumer

bicolor SZEPLIGETI — ITURI, BÉNI À LESSE

Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 394 (1911) (*Platybracon*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 405 (1914)

calviniæ CAMERON — NYASALAND, CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 53 (1906) (*Iphiaulax*)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 394 (1911) (*Platybracon*)
BRUES, Ann. South African Mus., vol. 19, p. 68 (1924) (*Platybracon*)

conradti SCHULZ — FERNANDO PO, TOGO, TRIPOLI

Spolia Hymenop., p. 290 (1906) (*Platybracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

curiosus SZÉPLIGETI — SOMALILAND, TANGANYIKA TERRITORY

Rés. Sci., Voyage Alluaud, p. 169 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

kriechbaumeri KOHL — SOUTHERN ARABIA

Denkschr. Akad. Wiss. Wien, vol. 71, p. 288 (1907)

nigriscapus SZÉPLIGETI — BELGIAN CONGO

Rev. Zool. Africaine, vol. 3, p. 405 (1914)

planinotus BRUES — CAPE PROVINCE

Ann. South African Mus., vol. 19, p. 68 (1924) (*Platybracon*)
CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 21 (1909) (*Doryctocephalus platynotus*) (non *Iphiaulax, Odontoscapus, platynotus* Cameron, 1905)

platynotus CAMERON — NYASALAND, CAPE PROVINCE

Rec. Albany Mus., vol. 1, p. 241 (1905) (*Iphiaulax*) (non *platynotus* Cameron, 1906)
CAMERON, Ann. South African Mus., vol. 5, p. 53 (1906) (*Iphiaulax erythrostomus*)

SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 394 (1911) (*Platybracon*)
BRUES, Ann. South African Mus., vol. 19, p. 68 (1924) (*Platybracon*)

varistigma KRIECHBAUMER — MOZAMBIQUE
Mem. Accad. Sci. Bologna, (5), vol. 4, p. 154 (1894)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

Schiztobracon CAMERON

Ann. South African Mus., vol. 5, p. 70 (1906)
ROMAN, Ent. Tidskr., vol. 31, p. 138 (1910) (*Tricœlopyge*)
Type: *S. ornaticollis* Cameron

ornatipennis CAMERON — TANGANYIKA TERR., SOUTHERN AFRICA
Ann. South African Mus., vol. 5, p. 70 (1906)
CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 24 (1909) (*latilobatus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 169 (1914)
BRUES, Ann. South African Mus., vol. 19, p. 68 (1924)

pulchrus ROMAN — CAFFRARIA
Ent. Tidskr., vol. 31, p. 139 (1910) (*Tricœlopyge*)

trisinuatus BRUES — NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 235 (1926)

Atanycolus Förster

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 238 (1862)
Type: *A.* (*Ichneumon*) *denigrator*

africanus SZÉPLIGETI — TANGANYIKA TERRITORY
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., 1907–08, vol. 3, p. 394 (1911)

striatus SZÉPLIGETI — TANGANYIKA TERRITORY
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 27 (1910)

tunetensis MARSHALL — TUNIS
Bull. Mus. Hist. Nat., Paris, p. 372 (1900)

Odontogaster SZÉPLIGETI

Ann. Mus. Nat. Hungarici, vol. 4, p. 551 (1906)
CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 22 (1909) (*Cænoprymnus*)
ROMAN, Ent. Tidskr., vol. 31, p. 135 (1910)
Type: *O. minor* Szépligeti

abyssinica Szépligeti — Abyssinia

Ann. Mus. Nat. Hungarici, vol. 11, p. 593 (1913)

atripes Brues — Uganda, Tanganyika Territory

Proc. American Acad. Arts Sci., vol. 61, p. 237 (1926)

bicolor Szépligeti — Eastern Equatorial Africa

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 28 (1910)
Szépligeti, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 394 (1911)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 160 (1914)
Szépligeti, Rés. Sci., Voyage Alluaud, p. 169 (1914)

camerunensis Szépligeti — Camerun, Nyasaland, Madagascar

Ann. Mus. Nat. Hungarici, vol. 3, p. 29 (1905) (*Iphiaulax*)
Szépligeti, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 396 (1911) (*cameruniensis*)
Enderlein, Arch. Naturg., Jahrg. 84A, Heft 11, p. 61 (1920)

caudata Szépligeti — Eastern Equatorial Africa

Ann. Mus. Nat. Hungarici, vol. 11, p. 593 (1913)

guineënsis Szépligeti — Guinea

Mitt. Zool. Mus., Berlin, vol. 7, p. 161 (1914)

madagascariensis Szépligeti — Madagascar

Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 420 (1913)
Szépligeti, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 140 (1915)

minor Szépligeti — Zululand, Tanganyika Territory

Ann. Mus. Nat. Hungarici, vol. 4, p. 551 (1906)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 161 (1914)
Brues, Ann. South African Mus., vol. 19, p. 70 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 238 (1926)

nana Szépligeti — Tunis, Belgian Congo?

Mitt. Zool. Mus., Berlin, vol. 7, p. 161 (1914)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 238 (1926)

nigripes Szépligeti — Belgian Congo, Uganda, Tanganyika Territory

Mitt. Zool. Mus., Berlin, vol. 7, p. 161 (1914)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 405 (1914)
Brues, Proc. American Acad. Arts. Sci., vol. 61, p. 238 (1926)

spinosa Cameron — Belgian Congo, Tanganyika Territory., South Africa

Arch. Math. Naturvidens., vol. 30, No. 10, p. 22 (1909) (*Cænoprymnus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 161 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 405 (1914)
BRUES, Ann. South African Mus., vol. 19, p. 69 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 238 (1926)

uniformis BRUES ZULULAND, ZANZIBAR
Ann. South African Mus., vol. 19, p. 70 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 238 (1926)

variegatus SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 161 (1914)

Mesobracon SZÉPLIGETI

Termes. Füzetek, vol. 25, p. 46 (1902)
CAMERON, Ann. South African Mus., vol. 5, p. 76 (1906) (*Telerda*)
ROMAN, Ent. Tidskr., vol. 31, p. 132, 135 (1910)
TURNER, Ann. Mag. Nat. Hist., (8), vol. 20, p. 245 (1917)
Type: *M. atripennis* Szépligeti

atripennis SZÉPLIGETI KALAHARI
Mitt. Zool. Mus., Berlin, vol. 190 (1914)

capensis SZÉPLIGETI CAPE PROVINCE
Mitt. Zool. Mus., Berlin, vol. 7, p. 189 (1914)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 241 (1926)

elegans SZÉPLIGETI CAMERUN
Ent. Mitt., vol. 2, p. 385 (1913)

guineënsis SZÉPLIGETI GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 189 (1914)

luteus CAMERON ZANZIBAR
Zeits., Naturwiss., vol. 81, p. 434 (1909) (*Telerda*)

maculiceps CAMERON EASTERN EQUATORIAL AFRICA, CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 76 (1906) (*Telerda*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 597 (1906) (*concolor*)
CAMERON, Zeits Naturwiss., vol. 81, p. 434 (1909) (*Telerda*)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 36 (1910) (*concolor*)

SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 406 (1911)
TURNER, Ann. Mag. Nat. Hist., (8), vol. 20, p. 245 (1917)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 189 (1914) (*concolor*)

minor BRUES — NATAL
Proc. American Acad. Arts. Sci., vol. 61, p. 240 (1926)

niger SZÉPLIGETI — NATAL
Ann. Mus. Nat. Hungarici, vol. 4, p. 596 (1906)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 240 (1926)

nigriceps CAMERON — CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 76 (1906)

nigricornis SZÉPLIGETI — GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 189 (1914)

pedalis BRUES — UGANDA
Proc. American Acad. Arts Sci., vol. 61, p. 241 (1926)

pulchripennis SZÉPLIGETI — CONGO, NYASALAND
Termes Füzetek, vol. 25, p. 46 (1902)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 406 (1911)

punctatus SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 190 (1914)

similis SZÉPLIGETI — SIERRA LEONE, SPANISH GUINEA, UGANDA
Ann. Mus. Nat. Hungarici, vol. 4, p. 597 (1906)
SZÉPLIGETI, ibid., vol. 6, p. 397 (1908)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 189 (1914)
SZÉPLIGETI, Ann. Ent. Soc. Belgique, vol. 58, p. 114 (1914)

trimaculatus SZÉPLIGETI — CAPE PROVINCE
Mitt. Zool. Mus., Berlin, vol. 7, p. 189 (1914)

truncatus SZÉPLIGETI — CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 190 (1914)

Rhytimorpha SZÉPLIGETI

Termes. Füzetek, vol. 24, p. 359 (1901)
Type: *R. coccinea* Szépligeti

coccinea SZÉPLIGETI — EQUATORIAL AND SOUTHWEST AFRICA
Termes. Füzetek, vol. 24, p. 359 (1901)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 551 (1906)

SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 155 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 110 (1914)
BRUES, Ann. South African Mus., vol. 19, p. 71 (1924)

nigriceps SZÉPLIGETI — MOZAMBIQUE
Ann. Mus., Nat. Hungarici, vol. 4, p. 551 (1906)

Curriea ASHMEAD

Proc. U. S. Nat. Mus., vol. 23, p. 50 (1900)
SZÉPLIGETI, Termes. Füzetek, vol. 23, p. 50 (1900)
ASHMEAD, Ent. News, vol. 15, p. 18 (1904)
Type: *C. fasciatipennis* Ashmead

antefurcalis SZÉPLIGETI — CAMERUN, BELGIAN CONGO
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 139 (1915)

fasciatipennis ASHMEAD — CAMERUN, LIBERIA, TOGO
Ent. News., vol. 15, p. 18 (1904)
SZÉPLIGETI, Ent. Mitt., vol. 2, p. 383 (1913)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 28 (1910)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

fenestrata SZÉPLIGETI — TOGO
Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

flavomaculata CAMERON — TANGANYIKA TERRITORY, CAPE PROVINCE
Rec. Albany Mus., Grahamstown, vol. 1, p. 157 (1905) (*Megalommum*)
CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 24 (1909)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 28 (1910)
BRUES, Ann. South African Mus., vol. 19, p. 71 (1924)

nigriventris SZÉPLIGETI — CAMERUN
Ent. Mitt., vol. 2, p. 383 (1913)

pulchripennis SZÉPLIGETI — TANGANYIKA TERRITORY
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 28 (1910)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

simplex BRUES — SOUTHERN RHODESIA
Proc. American Acad. Arts Sci., vol. 61, p. 242 (1926)

striata CAMERON — DELAGOA BAY, ZULULAND
Arch. Math. Naturvidens., vol. 30, No. 10, p. 24 (1909)
BRUES, Ann. South African Mus., vol. 19, p. 72 (1924)

testacea CAMERON — DELAGOA BAY
Arch. Math. Naturvidens., vol. 30, No. 10, p. 25 (1909)

testaceipes SZÉPLIGETI — CAMERUN, FRENCH CONGO, SPANISH GUINEA
Ann. Soc. Ent. Belgique, vol. 58, p. 109 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

transiens SZÉPLIGETI — NORTH CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 158 (1914)

Rhamnura ENDERLEIN

Zool., Anz., vol. 29, p. 195 (1905)
ROMAN, Ent. Tidskr., vol. 31, p. 137 (1910)
Type: *R. capillicauda* Enderlein

bicolor SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 162 (1914)

capillicauda ENDERLEIN — TOGO, CAMERUN, SPANISH GUINEA
Zool. Anz., vol. 29, p. 196 (1905)
SZÉPLIGETI, Ent. Mitt., vol. 2, p. 384 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 161 (1914)

crinicauda ENDERLEIN — NORTH CAMERUN
Zool. Anz., vol. 29, p. 196 (1905)

filicauda ENDERLEIN — CAMERUN
Zool. Anz., vol. 29, p. 195 (1905)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 140 (1915)

longiseta SZÉPLIGETI — WESTERN EQUATORIAL AFRICA
Ann. Mus. Nat. Hungarici, vol. 3, p. 28 (1905) (*Iphiaulax*)
SZÉPLIGETI, Ark. Zool., vol. 2, No. 14, p. 3 (1905) (*Iphiaulax*)
ENDERLEIN, Zool. Anz., vol. 29, p. 197 (1905)
ROMAN, Ent. Tidskr., vol. 31, p. 137 (1910)
SZÉPLIGETI, Ent. Mitt., vol. 2, p. 384 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 161 (1914)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 140 (1915)

seticauda ENDERLEIN — NORTH CAMERUN
Zool. Anz., vol. 29, p. 197 (1905)

tenuicornis ENDERLEIN TOGO
Zool., Anz., vol. 29, p. 198 (1905)

Bacuma CAMERON

Ann. South African Mus., vol. 5, p. 68 (1906)
? SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 549 (1906) (*Trachybracon*)

Type: *B. maculiventris* Cameron

fumipennis CAMERON CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 69 (1906)
CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 27 (1909)

maculiventris CAMERON SOUTHERN RHODESIA
Ann. South African Mus., vol. 5, p. 68 (1906)
CAMERON, Arch. Math. Naturvidens., vol. 30, No. 10, p. 27 (1909)

rufa CAMERON KENYA COLONY, TRANSVAAL; SOUTHWEST AFRICA
Arch. Math. Naturvidens., vol. 30, No. 10, p. 26 (1909)
CAMERON, Ann. Transvaal Mus., vol. 2, p. 194 (1911)
BRUES, Ann. South African Mus., vol. 19, p. 72 (1924)

Chelonogastra ASHMEAD

Proc. U. S. Nat. Mus., vol. 23, p. 139 (1900)
ASHMEAD, ibid., vol. 30, p. 195 (1906)
ROMAN, Ent. Tidskr., vol. 31, p. 119 (1910)
ROMAN, ibid., t.c., p. 133 (1910) (*Monocoila*)
TURNER, Ann. Mag. Nat. Hist. (9), vol. 10, p. 272 (1922) (*Monocoila*)
ENDERLEIN, Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 111 (1920) (*Ectemnoplax*)
BRUES, Ann. South African Mus., vol. 19, p. 73 (1924)

Type: *C. koebelei* Ashmead

elongatula BRUES CAPE PROVINCE
Ann. South African Mus., vol. 19, p. 74 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 245 (1926)

innotata TURNER CAPE PROVINCE
Ann. Mag. Nat. Hist., (9), vol. 10, p. 272 (1922) (*Monocoila*)

lurida ENDERLEIN South Africa
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 111 (1920) (*Ectomnoplax*)

natalensis BRUES NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 245 (1926)
orbiculata BRUES ZULULAND
Ann. South African Mus., vol. 19, p. 75 (1924)
pectoralis HOLMGREN CAPE PROVINCE
Eugen. Resa, Ins., vol. 2, p. 424 (1868) (*Bracon*)
DALLA TORRE, Cat. Hymen., vol. 4, p. 272 (1898) (*Bracon holmgreni*)
ROMAN, Ent. Tidskr., vol. 31, p. 133 (1910) (*Monocoila*)
rotundula BRUES ZULULAND
Ann. South African Mus., vol. 19, p. 73 (1924)
secunda SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 176 (1914) (*Monocoila*)
signata TURNER CAPE PROVINCE
Ann. Mag. Nat. Hist., (9), vol. 10, p. 272 (1922) (*Monocoila*)

Gastrotheca GUÉRIN
Léfébure, Voyage Abyss., vol. 6, p. 348 (1848)
Type: *G. furcata* Guérin

areolata CAMERON TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 202 (1911)
bilobata CAMERON CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 35 (1906)
bituberculata SZÉPLIGETI CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 209 (1914)
bivittata KRIECHBAUMER DELAGOA BAY
Berliner Ent. Zeits., vol. 39, p. 314 (1894)
capensis ENDERLEIN PONDOLAND
Stettiner Ent. Zeitg., vol. 66, p. 235 (1905)
capra ENDERLEIN TANGANYIKA TERRITORY
Stettiner Ent. Zeitg., vol. 66, p. 234 (1905)
caudata SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 209 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 414 (1914)
excisa SZÉPLIGETI KAPIRI
Rev. Zool. Africaine, vol. 3, p. 414 (1914)

furcata GUÉRIN SPANISH GUINEA, CONGO, TANGANYIKA, ABYSSINIA

Lefebure, Voy. Abyssinie, p. 349, pl. 7, fig. 4 (1848)
CAMERON, Ann. South African Mus., vol. 5, p. 35 (1906)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 28 (1910)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 412 (1911)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 116 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 208 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 415 (1914)
SZÉPLIGETI, Rés. Sci., Voyage Alluaud, p. 186 (1914)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 150 (1915)

longiseta SZÉPLIGETI BELGIAN CONGO

Rev. Zool. African, vol. 3, p. 414 (1914)

melanocera CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 201 (1911)

sulphurea SZÉPLIGETI TANGANYIKA TERRITORY

Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 425 (1913)

trimaculata CAMERON CAPE PROVINCE

Ann. Transvaal Mus., vol. 2, p. 201 (1911)

Glyptomorpha HOLMGREN

Eugenia Resa, Ins., p. 427 (1868)
SZÉPLIGETI, Termes. Füzetek, vol. 19, p. 167, 230 (1896) (*Pseudovipio*)
ROMAN, Ent. Tidskr., vol. 31, p. 124 (1910)

Type: *G. ferruginea* Holmgren

algirica LUCAS ALGERIA, EASTERN AFRICA, CAPE PROVINCE

Expl. Sci. Algérie, Zool., vol. 3, p. 336, pl. 19, fig. 8 (1846) (*Vipio*)
MARSHALL, André, Spec. Hymén. Europe Algérie, vol. 5bis, p. 29 (1897) (*Vipio formidabilis*)
MARSHALL, ibid., vol. 5bis, p. 37 (*Vipio*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 548 (1906)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 393 (1911)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 156 (1914)
Note.—This may be the same as *Vipio desertor* Fabricius.

andrieui VUILLET — SENEGAL

Insecta, Rennes, vol. 2, p. 153 (1912) (*Vipio; Pseudov pio*)

apicalis SZÉPLIGETI — TANGANYIKA TERRITORY TRANSVAAL

Ann. Mus. Nat. Hungarici, vol. 4, p. 548 (1906)
SZÉPLIGETI, Bull. Mus. Hist. Nat., Paris, 1907, p. 34 (1907)
ROMAN, Ent. Tidsk., vol. 31, p. 125 (1910)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 26 (1910)

bætica SPINOLA var. **mauritanica** SZÉPLIGETI — MOROCCO

Ann. Mus. Nat. Hungarici, vol. 4, p. 548 (1906)

? **bellosus** SMITH — SOUTHWEST AFRICA

Trans. Ent. Soc. London, 1870, p. 531 (1870) (*Bracon*)
DALLA TORRE, Cat. Hymen., vol. 4, p. 275 (1898) (*Bracon kinsembo*)

bequaerti SZÉPLIGETI — BELGIAN CONGO

Rev. Zool. Africaine, vol. 3, p. 403 (1914)

bifasciata SZÉPLIGETI — FRENCH CONGO

Rev. Zool. Africaine, vol. 3, p. 404 (1914)

concolor SZÉPLIGETI — BRITISH EAST AFRICA, DELAGOA BAY

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 393 (1911)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 109 (1914)

dubia SZÉPLIGETI — TANGANYIKA TERRITORY

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 26 (1910)

elongata SZÉPLIGETI — TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 156 (1914)

erythræana SZÉPLIGETI — ERYTHREA

Ann. Mus. Nat. Hungarici, vol. 11, p. 592 (1913)

ferruginea HOLMGREN — CAPE PROVINCE

Eugenies Resa, Ins., p. 427, pl. 8, fig. 4 (1868)

intermedia SZÉPLIGETI — ALGERIA (Europe)

Termes. Füzetek, vol. 19, p. 165, 228 (1896)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 4, p. 458 (1906)

longiseta SZÉPLIGETI — BRITISH EAST AFRICA

Rés. Sci., Voyage Alluaud, p. 168 (1914)

maculata SZÉPLIGETI — BELGIAN CONGO, UGANDA, TANGANYIKA TERR.

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 25 (1910)

SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 403 (1914)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 246 (1926)

orientalis SZÉPLIGETI KENYA COLONY

Rés. Sci., Voyage Alluaud, p. 168 (1914)

punctidorsis BRULLÉ SENEGAL, GUINEA, EAST AFRICA

Hist. Nat. Ins. Hymen, vol. 4, p. 444 (1846) (*Vipio*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 156 (1914)
SZÉPLIGETI, Rés. Sci., Voyage Alluaud, p. 168 (1914)

rufiscapus SZÉPLIGETI TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 156 (1914)

rugosa SZÉPLIGETI BELGIAN CONGO, TANGANYIKA TERR, NYASALAND, MOZAMBIQUE

Ann. Mus. Nat. Hungarici, vol. 11, p. 404 (1913)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 404 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 156 (1914)

tegularis SZÉPLIGETI Cape Province

Mitt. Zool. Mus., Berlin, vol. 7, p. 156 (1914)

tentator ROSSI ALGERIA (Europe)

Fauna Etrusca, vol. 2, p. 50 (1790) (*Ichneumon*).
NEES, Hymen. Icyneumon. affin. Monogr., vol. 1, p. 111 (1834) (*Bracon*)
MARSHALL, Spéc. Hymén. Europe Algérie, vol. 4, p. 87 (1888) (*Bracon*)
SZÉPLIGETI, Termes. Füzetek, vol. 19, p. 167 (1896) (*Pseudovipio*)
SCHMIEDEKNECHT, Illustr. Wochenschr. Ent., vol. 1, p. 511 (1896) (*Vipio*)

Odesia CAMERON

Ann. South African Mus., vol. 5, p. 79 (1896)

Type: *O. longicornis* Cameron

decemmaculata CAMERON TRANSVAAL

Zeits. Naturwiss., vol. 81, p. 435 (1909)

longicornis Cameron SOUTH AFRICA

Ann. South African Mus., vol. 5, p. 80 (1906)
CAMERON, Zeits Naturwiss., vol. 81, p. 435 (1909)
BRUES, Ann. South African Mus., vol. 19, p. 77 (1924)

pulchripes SZÉPLIGETI TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 155 (1914)

Nundinella SZÉPLIGETI

Mitt. Zool. Mus., Berlin, vol. 7, p. 157 (1914)

Type: *N. gracilis* Szépligeti

gracilis SZÉPLIGETI — TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 157 (1914)

Endovipio TURNER

Ann. Mag. Nat. Hist. (9), vol. 10, p. 273 (1922)

Type: *E. ceresensis* Turner

ceresensis TURNER — CAPE PROVINCE

Ann. Mag. Nat. Hist. (9), vol. 10, p. 273 (1922)

Euvipio SZÉPLIGETI

Genera Insect., fasc. 22, p. 14 (1904)

Type: *E. rufa* Szépligeti

commensalis BEQUAERT — DAHOMEY

Bull. Soc. Ent. France, 1916, p. 102 (1916)

facialis SZÉPLIGETI — CONGO, TANGANYIKA TERRITORY, MADAGASCAR

Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 422 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 157 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 109 (1914)

maculiceps SZÉPLIGETI — TANGANYIKA TERRITORY

Mitt. Zool Mus., Berlin, vol. 7, p. 157 (1914)

nigripennis SZÉPLIGETI — BELGIAN CONGO

Rev. Zool. Africaine, vol. 3, p. 404 (1914)

rufus SZÉPLIGETI — SIERRA LEONE, BELGIAN CONGO, TANGANYIKA TERR.

Genera Insect., fasc. 22, p. 15 (1904)
SZÉPLIGETI, Ann. Mus., Nat. Hungarici, vol. 4, p. 547 (1906)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 393 (1911)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 404 (1914)

signatus SZÉPLIGETI — CONGO

Ann. Soc. Ent. Belgique, vol. 58, p. 109 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 157 (1914)

unifasciatus BRULLÉ — SENEGAL, FRENCH & BELGIAN CONGO, TANGANYIKA TERR.

Hist. Nat. Ins. Hymén, vol. 4, p. 446 (1846) (*Vipio*)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 157 (1914)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 404 (1914)

Vipio Latreille

Hist. Nat. Crust. et Ins., vol. 13, p. 176 (1805)
Type: *V. desertor* Fabricius

abdelkader Schmiedeknecht — Algeria
Illustr. Wochenschr. Ent., vol. 1, p. 498 (1896)
Marshall, Hymén. Europe et Algérie, vol. 5bis, p. 253 (1898)

carnifex Kriechbaumer — Mozambique
Berliner Ent. Zeits., vol. 39, p. 311 (1894)

coronatus Brullé — Madagascar
Hist. Nat. Ins. Hymén., vol. 4, p. 448 (1846)

curticaudis Szépligeti — Algeria (Europe)
Termes. Füzetek, vol. 19, p. 166 (1896)
Szépligeti, ibid., t.c., p. 229 (1896) (*brevicaudis*)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 22 (1897)

desertor Fabricius — Algeria, Delagoa Bay (Europe)
Syst. Ent., p. 334 (1775) (*Ichneumon*)
? Lucas, Explor. Sci., Algérie, Zool., vol. 3, p. 336 (1846)
Schultess-Schindler, Bull. Soc. Vaudois, vol. 35, p. 250 (1899) (*Vipio*)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 71 (1888)

dorsimacula Brullé — Cape Province
Hist. Nat. Ins. Hymén., vol. 4, p. 445 (1846)

fasciipennis Brullé — Senegal
Hist. Nat. Ins. Hymén., vol. 4, p. 446 (1846)

forticarinatus Cameron — Cape Province
Arch. Math. Naturvidens., vol. 30, No. 10, p. 21 (1909)

fumipennis Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 64 (1906)
Brues, ibid., vol. 19, p. 77 (1924)

indecisus Walker — Egypt
List. Hymen. Egypt. p. 5 (1871) (*Bracon*)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 172 (1888) (*Bracon*)

longicaudis Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 65 (1906)

longicollis Buysson — Transvaal
Ann. Soc. Ent. France, vol. 66, p. 353 (1897)

maculiceps Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 62 (1906)

marshalli Schmiedeknecht — Algeria
Illustr. Wochenschr. Ent., vol. 1, p. 511 (1896)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 19 (1897)

melanopus Cameron — Transvaal
Ann. Transvaal Mus., vol. 2, p. 193 (1911)

michaelseni Szépligeti — British Southwest Africa
Beitr. Landf. Südwestafrikas, vol. 1, p. 186 (1918)

natalensis Cameron — Natal
Ann. South African Mus., vol. 5, p. 63 (1906)

nigronotatus Brullé — Cape Province
Hist. Nat. Ins. Hymén., vol. 4, p. 442 (1846)
Cameron, Ann. South African Mus., vol. 5, p. 60 (1906)

nigripalpis Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 63 (1906)

nominator Fabricius — Algeria (Europe)
Ent. Syst., vol. 2, p. 155 (1793) (*Ichneumon*)
Nees, Hymen. Ichneum. affin. Monogor., vol. 1, p. 109 (1834) (*Bracon*)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 73 (1888)
Marshall, ibid., vol. 5bis, p. 22 (1897)

ochreatus Kriechbaumer — Mozambique
Mem. Accad. Sci., Bologna, (5), vol. 4, p. 155 (1896)

pallidinervis Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 61 (1906)

? **pallidiventris** Cameron — Transvaal
Ann. Transvaal Mus., vol. 2, p. 194 (1911)

quinquemaculatus Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 66 (1906)

sexfoveatus Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 67 (1906)

signifer WALKER RED SEA

List Hymen. Egypt, p. 5 (1871) (*Bracon*)

spilocephalus CAMERON CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 66 (1906)

spilogaster WALKER EGYPT

List. Hymen. Egypt, p. 5 (1871) (*Bracon*)

Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 172 (1888) (*Bracon*)

stictonotus CAMERON SOUTHERN RHODESIA

Ann. South African Mus., vol. 5, p. 64 (1906)

tinctipennis CAMERON CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 61 (1906)

transvaalensis CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 193 (1911)

trimaculatus CAMERON CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 60 (1906)

xanthomelas WALKER EGYPT

List Hymen. Egypt. p. 5 (1871) (*Bracon*)

MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 172 (1888) (*Bracon*)

DALLA TORRE, Cat. Hymen., vol. 4, p. 294 (1898) (*walkeri*)

Liomorpha SZÉPLIGETI

Mitt. Zool. Mus., Berlin, vol. 7, p. 155 (1914)

Type: *L. nigrirostris* Szépligeti

nigrirostris SZÉPLIGETI TUNIS

Mitt. Zool. Mus., Berlin, vol. 7, p. 155 (1914)

Aphrastobracon ASHMEAD

Proc. U. S. Nat. Mus., vol. 18, p. 646 (1896)

Type: *A. flavipennis* Ashmead

Note. The species here listed might be sought under Iphiaulax or Pseudobracon.

gratiosus ENDERLEIN FERNANDO PO

Arch. Naturg., Jahrg. 84A, Heft 11, p. 53 (1920)

guttifer ENDERLEIN CAMERUN

Arch. Naturg., Jahrg. 84A, Heft 11, p. 53 (1920)

Trigastrotheca CAMERON

Ann. South African Mus., vol. 5, p. 32 (1906)
BRUES, ibid., vol. 19, p. 109 (1924)

Type: *T. triloba* Cameron

nigricornis CAMERON — CAPE PROVINCE

Zeits. Naturwiss., vol. 81, p. 439 (1909)

trilobata CAMERON — SOUTHERN RHODESIA

Ann. South African Mus., vol. 5, p. 32 (1906)

Esenga CAMERON

Ann. South African Mus., vol. 5, p. 36 (1906)

Type: *E. ovata* Cameron

ovata CAMERON — CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 36 (1906)

SUBFAMILY DORYCTINÆ

Gymnobracon SZÉPLIGETI

Termes. Füzetek, vol. 25, p. 43 (1903)
Brullé, Hist. Nat. Ins. Hymén., vol. 4, p. 454 (1846) (*Syngaster*, Section 1)
SZÉPLIGETI, Genera Insect., fasc. 22, p. 67 (1904)

Type: *G. brasiliensis* Szépligeti

luteus Brullé — SENEGAL

Hist. Nat. Ins. Hymén., vol. 4, p. 457 (1846) (*Syngaster*)
SZÉPLIGETI, Genera Insect., fasc. 22, p. 67 (1904)

Rhaconotus RUTHE

Stettiner Ent. Zeitg., vol. 15, p. 349 (1854)

Type: *R. aciculatus* Ruthe

spathulatus SZEPLIGETI — CAMERUN, BELGIAN CONGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 198 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 413 (1914)

Dendrosoter WESMAEL

Nouv. Mém. Acad. Sci., Bruxelles, vol. 11, p. 137 (1838)

Type: *D. protuberans* Nees

camerunus ENDERLEIN — CAMERUN

Arch. Naturg., Jahrg. 78A, Heft 2, p. 36 (1912)

interstitialis SZÉPLIGETI — TANGANYIKA TERRITORY
Bull. Mus. Hist. Nat. Paris, 1907, p. 35 (1907)
niger SZÉPLIGETI — TOGO, CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 197 (1914)

Doryctes HALIDAY

Ent. Mag., vol. 4, p. 43 (1836)
Type: *D. striatellus* Nees

liogaster MARSHALL — TUNIS
Bull. Mus. Hist. Nat. Paris, p. 372 (1899)
variegatus SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 201 (1914)

Neodoryctes SZÉPLIGETI

Mitt. Zool. Mus., Berlin, vol. 7, p. 199 (1914)
Type: *N. thoracicus* Szépligeti

niger SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 201 (1914)
pilosipes SZÉPLIGETI — TOGO
Mitt. Zool. Mus., Berlin, vol 7, p. 200 (1914)
pulchricaudis SZÉPLIGETI — BELGIAN CONGO
Rev. Zool. Africaine, vol. 3, p. 413 (1914)
testaceus SZÉPLIGETI — TOGO
Mitt. Zool. Mus., Berlin, vol. 7, p. 199 (1914)
thoracicus SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin vol. 7, p. 200 (1914)
transversalis SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 199 (1914)
xanthocephalus SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 200 (1914)

Glyptodoryctes ASHMEAD

Proc. U. S. Nat. Mus., vol. 23, p. 144 (1900)
Type: *G. caryæ* Ashmead

coxalis SZÉPLIGETI — KENYA COLONY
Rés. Sci. Voyage Alluaud, p. 175 (1914)

Pseudodoryctes Szépligeti

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 149 (1915)

Type: *P. tricolor* Szépligeti

annulicornis Szépligeti — Camerun

Mitt. Zool. Mus., Berlin, vol. 7, p. 198 (1914)

camerunus Szépligeti — Camerun, Togo, Lagos

Ann. Soc. Ent. Belgique, vol. 58, p. 115 (1914)

Szépligeti, Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 102 (1913)

Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 198 (1914)

concolor Szépligeti — Camerun, Spanish Guinea

Mitt. Zool. Mus., Berlin, vol. 7, p. 198 (1914)

femoralis Szépligeti — Kenya Colony

Rés. Sci. Voyage Alluaud, p. 176 (1914)

fenestratus Brues — Uganda

Proc. American Acad. Arts Sci., vol. 61, p. 246 (1926)

fulvipes Szépligeti — Camerun

Mitt. Zool. Mus., Berlin, vol. 7, p. 199 (1914)

setosus Szépligeti — Camerun

Mitt. Zool. Mus., Berlin, vol. 7, p. 198 (1914)

testaceus Szépligeti — Belgian Congo

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 149 (1915)

tricolor Szépligeti — Belgian Congo

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 149 (1915)

Biphymaphorus Szépligeti

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 407 (1911)

Type: *B. rufithorax* Szépligeti

bicolor Szépligeti — Togo

Mitt. Zool. Mus., Berlin, vol. 7, p. 195 (1914)

brevipetiolatus Szépligeti — Spanish Guinea

Mitt. Zool. Mus., Berlin, vol. 7, p. 195 (1914)

conradti Szépligeti — Togo

Mitt. Zool. Mus., Berlin, vol. 7, p. 194 (1914)

flavitarsis Szépligeti — Spanish Guinea

Mitt. Zool. Mus., Berlin, vol. 7, p. 194 (1914)

fulvus SZÉPLIGETI TOGO
Mitt. Zool. Mus., Berlin, vol. 7, p. 194 (1914)

guineënsis SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 194 (1914)
SZÉPLIGETI Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 102 (1913)

rufithorax SZÉPLIGETI UGANDA
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 408 (1911)

superbus SZÉPLIGETI SPANISH GUINEA, UGANDA
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 408 (1911)
SZEPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 195 (1914)

tessmanni SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 195 (1914)

variegatus SZÉPLIGETI UGANDA
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 408 (1911)

Odontobracon CAMERON

Biol. Centr. Amer., Hymen., vol. 2, p. 384 (1887)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 10 (1897) (*Zombrus*)
KRIECHBAUMER, Berliner Ent. Zeits., vol. 39, p. 60 (1894) (*Trimorus*, non Förster)
DALLA TORRE, Cat. Hymen., vol. 4, p. 250 (1896) (*Neotrimorus*)
SZÉPLIGETI, Termes. Füzetek, vol. 25, p. 47 (1902) (*Acanthobracon*)
CAMERON, Journ. Straits Br. Roy. Asiatic Soc., vol. 44, p. 104 (1905) *Trichiobracon*)

Type: *O. nigriceps* Cameron

antennalis SZÉPLIGETI FRENCH CONGO, CAMERUN, SPANISH GUINEA
Ann. Soc. Ent. Belgique, vol. 58, p. 115 (1914) (*Zombrus*)
Mitt. Zool. Mus., Berlin, vol. 7, p. 196 (1914) (*Zombrus*)

atriceps BRUES CAPE PROVINCE
Ann. South African Mus., Vol. 19, p. 140 (1924)
CAMERON, Zeits. Naturwiss., vol. 81, p. 442 (1909) (*nigriceps*, non Cameron, 1887)

baculiger ENDERLEIN CAMERUN, BELGIAN CONGO
Arch. Naturg., Jahrg. 78A, Heft 2, p. 29 (1912)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 148 (1915)

bimaculatus SZÉPLIGETI — TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 197 (1914) (*Zombrus*)

cameroni SZÉPLIGETI — SOMALILAND, DELAGOA BAY, TRANSVAAL

Ent. Mitt., vol. 2, p. 385 (1913) (*Zombrus*)
CAMERON, Zeits Naturwiss., vol. 81, p. 441 (1909) (*Zombrus rufus*, non Cameron, 1905)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 115 (1914) (*Zombrus*)

concolor SZÉPLIGETI — TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 196 (1914) (*Zombrus*)

croceipes nom. nov. — CAMERUN

ENDERLEIN, Arch. Naturg., 84A, Heft 11, p. 133 (1920) (*Zombrus flavipes*, non Cameron, 1912)

duplicatus BRUES — CAPE PROVINCE

Ann. South African Mus., vol. 19, p. 140 (1924)
CAMERON, Zeits. Naturwiss., vol. 81, p. 444 (1909) (*Zombrus luteus*, non *Neotrimorus luteus* Cameron, 1905)

erythrostomus CAMERON — BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 374 (1912) (*Zombrus*)

flaviceps CAMERON — BELGIAN CONGO, UGANDA

Ann. Soc. Ent. Belgique, vol. 56, p. 373 (1912) (*Zombrus*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 248 (1926)

fuscipennis SZÉPLIGETI — TOGO, CAMERUN, BELGIAN CONGO

Termes. Füzetek, vol. 25, p. 47 (1902) (*Acanthobracon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 197 (1914) (*Zombrus*)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 148 (1915) (*Zombrus*)

giganteus SZÉPLIGETI — TANGANYIKA TERRITORY

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 407 (1911) (*Zombrus*)

insularis SCHULZ — FERNANDO PO

Spolia Hymenop., p. 293 (1906) (*Neotrimorus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 197 (1914)

maculiceps CAMERON — MOZAMBIQUE

Ann. South African Mus., vol. 5, p. 78 (1906) (*Acanthobracon*)

maculifrons CAMERON — CAPE PROVINCE

Rec. Albany Mus., Grahamstown, vol. 1, p. 169 (1905) (*Trichiobracon*)

maculipennis BRULLÉ — SENEGAL

Hist. Nat. Ins. Hymén., vol. 4, p. 461 (1846) (*Syngaster*)

madagascariensis Marshall — MADAGASCAR

Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 12, (1897) (*Zombrus*)

magnus SZÉPLIGETI — TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 196 (1914) (*Zombrus*)

melanopterus CAMERON — BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 374 (1912) (*Zombrus*)

minor SZÉPLIGETI — BRITISH SOUTHWEST AFRICA

Beitr. Landf. Südwestafrikas, vol. 1, p. 190 (1918)

nigricornis BRULLÉ — SENEGAL

Hist. Nat. Ins. Hymen., vol. 4, p. 463 (1846) (*Syngaster*)

nigripennis KRIECHBAUMER . CENTRAL AND SOUTHERN AFRICA

Berliner Ent. Zeits., vol. 39, p. 60 (1894) (*Trimorus*)
CAMERON, Ann. Soc. Ent. Belgique, vol. 56, p. 374 (1912) (*Zombrus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 196 (1914) (*Zombrus*)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 115 (1914) (*Zombrus*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 412 (1914) (*Zombrus*)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 148 (1915)

nigripes CAMERON — TRANSVAAL

Ann. South African Mus., vol. 5, p. 79 (1906) (*Acanthobracon*)

nigromaculatus CAMERON — CAPE PROVINCE

Rec. Albany Mus., Grahamstown, vol. 1, p. 155 (1905) (*Zombrus*)

orientalis SZÉPLIGETI — TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 197 (1914) (*Zombrus*)

pedalis BRUES — CAPE PROVINCE

Ann. South African Mus., vol. 19, p. 141 (1924)
CAMERON, Zeits. Naturwiss., vol. 81, p. 442 (1909) (*Zombrus nigripes*, non Cameron, 1906)

pulcher SZÉPLIGETI — NORTH CAMERUN

Mitt. Zool. Mus., Berlin, vol. 7, p. 196 (1914) (*Zombrus*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 412 (1914) (*Zombrus*)

rufus CAMERON — CAPE PROVINCE

Rec. Albany Mus., Grahamstown, vol. 1, p. 168 (1905) (*Trichiobracon*)

semialbus SZÉPLIGETI — BELGIAN CONGO

Rev. Zool. Africaine, vol. 3, p. 412 (1914) (*Zombrus*)

semistriatus BRULLÉ — SENEGAL, TANGANYIKA TERRITORY

Hist. Nat. Ins. Hymén., vol. 4, p. 464 (1846) (*Syngaster*)
SZÉPLIGETI, Res. Sci. Voyage Alluaud, p. 175 (1914) (*Zombrus*)

similis SZÉPLIGETI — TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 4, p. 600 (1906) (*Zombrus*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 196 (1914) (*Zombrus*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 412 (1914) (*Zombrus*)

spilopterus CAMERON — CAPE PROVINCE, NATAL

Zeits. Naturwiss., vol. 81, p. 442 (1909) (*Zombrus*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 247 (1926)

thomseni SZÉPLIGETI — BRITISH SOUTHWEST AFRICA

Beitr. Landf. Südwestafrikas, vol. 1, p. 189 (1918) (*Zombrus*)

tuberculatus CAMERON — BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 374 (1912) (*Zombrus*)

wagneri SZÉPLIGETI — CAMERUN

Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 148 (1915) (*Zombrus*)
SZÉPLIGETI, Entom. Mitt., vol. 2, p. 385 (1913) (*Zombrus*)
SZÉPLIGETI, Ann. Ent. Soc. Belgique, vol. 58, p. 115 (1914) (*Zombrus*)

Priosphys ENDERLEIN

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 132 (1920)

Type: *P. denticulata* Enderlein

denticulata ENDERLEIN — CAMERUN

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 133 (1920)

Tebennotoma ENDERLEIN

Arch. Naturg., Jahrg. 78A, Heft 2, p. 36 (1912)

Type: *T. calvata* Enderlein

calvata ENDERLEIN — MADAGASCAR

Arch. Naturg., Jahrg. 78A, Heft 2, p. 37 (1912)

Xenolobus CAMERON

Ann. Transvaal Mus., vol. 2, p. 199 (1911)

Type: *X. rufus* Cameron

rufus CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 199 (1911)
BRUES, Ann. South African Mus., vol. 19, p. 80 (1924)

Latana Cameron

Ann. South African Mus., vol. 5, p. 77 (1906)

Type: *L. excavata* Cameron

excavata CAMERON NATAL

Ann. South African Mus., vol. 5, p. 78 (1906)

Udamolcus ENDERLEIN

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 143 (1920)

Type: *U. herero* Enderlein

flaviceps ENDERLEIN FERNANDO PO

Arch. Naturg. Jahrg. 84A (1918), Heft 11, p. 143 (1920)

herero ENDERLEIN BRITISH SOUTHWEST AFRICA

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 143 (1920)

SUBFAMILY EXOTHECINÆ

Phanomeris FÖRSTER

Verh. preuss. Rheinlande, vol. 235 (1862)

Type: *P. anbormis* Wesmael

dubius BINGHAM (probably a Doryctine) SOUTHERN RHODESIA

Trans. Ent. Soc. London, 1902, p. 546, pl. 18, fig. 59 (1902)

Cœloreuteus ROMAN

Ent. Tidskr., vol. 31, p. 112 (1910)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 36 (1910)

Type: *C. africanus* Szépligeti

africanus SZÉPLIGETI KILIMANDJARO

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 36 (1910)
Roman, Ent. Tidskr., vol. 31, p. 113 (1910)

testaceus SZÉPLIGETI TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 203 (1914)

Spinaria Brullé

Hist. Nat. Ins., Hymen, vol. 4, p. 512 (1846)
Ashmead, Canadian Entom., vol. 37, p. 7 (1905) (*Brownius*)

Type: *S. armator* Fabricius

inermis Guérin (generic position in doubt) Abyssinia
Léfébure, Voyage Abyssinie, vol. 6, p. 350, pl. 7, fig. 5 (1848)

Subfamily RHOGADINÆ

Phænodus Förster

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 241 (1862)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 95 (1897)
Szépligeti, Genera Insect., fasc. 22, p. 78 (1904)
Schmiedeknecht, Hymen. Mitteleuropas, p. 514 (1907)
Enderlein, Arch.Naturg., Jahrg. 84A (1918), Heft 11, p. 145 (1920)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 248 (1926)

Type: *P. pallipes* Marshall

africanus Brues Rhodesia
Proc. Amercan Acad. Arts Sci., vol. 61, p. 248 (1926)

Clinocentrus Haliday

Entom. Mag., vol. 1, p. 266 (1833)

Type: *C. umbratilis* Haliday

anticus Wollaston Madeira
Ann. Mag. Nat. Hist. (3), vol. 1, p. 24 (1858)

divisus Wollaston Madeira
Ann. Mag. Nat. Hist. (3), vol. 1, p. 24 (1858)

Bæocentrum Schulz

Zool. Ann., vol. 4, p. 65 (1910)
Szépligeti, Bull. Mus. Hist. Nat., Paris, 1907, p. 35 (1907) (*Brachycentrus*, nec Taschenberg, 1865)

Type: *B. minutum* Szépligeti

minutum Szépligeti Kenya Colony
Bull. Mus. Hist. Nat., Paris, 1907, p. 65 (1910)

Megarhogas Szépligeti

Genera Insect., fasc. 22, p. 83 (1904)

Type: *M. longipes* Szépligeti

albitarsus SZÉPLIGETI TANGANYIKA TERRITORY
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 410 (1911)

concolor SZÉPLIGETI TOGO, BELGIAN CONGO, NYASALAND
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 410 (1911)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 203 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 116 (1914)

nigriceps SZÉPLIGETI FERNANDO PO
Mitt. Zool. Mus., Berlin, vol. 7, p. 203 (1914)

persimilis SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 203 (1914)

Cystomastax SZÉPLIGETI

Genera Insect., fasc. 22, p. 81 (1904)
Type: *C. macrocentroides* Szépligeti

voeltzkowi SZÉPLIGETI MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 424 (1913)

Pelecystoma WESMAEL

Nouv. Mém. Acad. Sci., Bruxelles, vol. 11, p. 91 (1838)
SZÉPLIGETI, Termes Füzetek, vol. 23, p. 57 (1900) (*Macrostomion*)
ENDERLEIN, Arch Naturg., Jahrg. 84A (1918), Heft 11, p. 146 (1920)
Type: *P. luteum* Nees

africanum ENDERLEIN TANGANYIKA TERRITORY
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 147 (1920)

Cratodactyla SZÉPLIGETI

Rés. Sci.Voyage Alluaud, p. 180 (1914)
Type: *C. unicolor* Szépligeti

unicolor SZÉPLIGETI TANGANYIKA TERRITORY
Rés. Sci.,Voyage Alluaud, p. 180 (1914)

Heterogamus WESMAEL

Nouv. Mém. Acad. Sci. Bruxelles, vol. 11, p. 120 (1838)
Type: *H. dispar* Curtis

alluaudi SZÉPLIGETI KILIMANDJARO
Rés. Sci. Voyage Alluaud, p. 179 (1914)

crepidigera ENDERLEIN TANGANYIKA TERRITORY
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 151 (1920)

Rhogas NEES
Nouv. Act. Acad. Nat. Curios., vol. 9, p. 306 (1818)
Type: *R. heterogaster* Wesmael

æqualis SZÉPLIGETI TOGO
Mitt. Zool. Mus., Berlin, vol. 7, p. 204 (1914)

africanus SZÉPLIGETI NYASALAND, KENYA COLONY, TANGANYIKA TERR., MADAGASCAR
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 37 (1910)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 6, p. 400.
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 411 (1911)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 424 (1913)

annulicornis SZÉPLIGETI MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 425 (1913)

annulifemur ENDERLEIN TANGANYIKA TERRITORY
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 154 (1920)

annulipes CAMERON SEYCHELLES
Trans. Linn. Soc. London, Zool. (2), vol. 12, p. 83 (1907) (*Camptocentrus*)

areolatus SZÉPLIGETI KENYA COLONY
Rés. Sci., Voyage Alluaud, p. 181 (1914)

asmaranus ENDERLEIN ERITREA
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 154 (1920)

atripes SZÉPLIGETI KENYA COLONY
Rés. Sci., Voyage Alluaud, p. 181 (1914)

bevisi BRUES NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 253 (1926)

bicolor LUCAS ALGERIA
Expl. Sci. Algérie, Zool., vol. 1, p. 336 (1846)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 305 (1888)

capensis CAMERON CAPE PROVINCE
Rec. Albany Mus., Grahamstown, vol. 1, p. 243 (1905)

caudatus SZÉPLIGETI ABYSSINIA
Ann. Mus. Nat. Hungarici, vol. 11, p. 600 (1913)

circumscriptus NEES — NORTHERN AFRICA (Europe)
Hymen. Ichneum. affin. Monogr., vol. 1, p. 216 (1834)
MARSHALL, Trans. Ent. Soc. London, 1885, p. 98 (1885)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 298 (1888)

citernii MANTERO — SOMALILAND
Ann. Mus. Civ. Stor. Nat. Genova, (3), vol. 41, p. 414 (1905)

dedivus SZÉPLIGETI — TOGO
Mitt. Zool. Mus., Berlin, vol. 7, p. 204 (1914)

deminutus SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 203 (1914)

dimidiatus SPINOLA — NORTHERN AFRICA (Europe)
Insect. Ligur., vol. 2, p. 123 (1808) (*Bracon*)
NEES, Hymen. Ichneum. affin. Monogr., vol. 1, p. 214 (1834)
MARSHALL, Trans. Ent. Soc. London, 1885, p. 91 (1885)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 283 (1888)

elongatus SZÉPLIGETI — BELGIAN CONGO
Rev. Zool. Africaine, vol. 3, p. 413 (1914) (*Camptocentrus* ?)

excisus SZÉPLIGETI — MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 424 (1913)

flavomarginatus SZÉPLIGETI — KILIMANDJARO, 12,000 FT.
Mitt. Zool. Mus., Berlin, vol. 7, p. 205 (1914)

hemipterus MARSHALL — TUNIS
Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 137 (1897)

inæqualis SZÉPLIGETI — SOMALILAND
Mitt. Zool. Mus., Berlin, vol. 7, p. 204 (1914)

insignis BRUES — UGANDA
Proc. American Acad. Arts Sci., vol. 61, p. 251 (1926)

longipes SZÉPLIGETI — KENYA COLONY
Ann. Mus. Nat. Hungarici, vol. 4, p. 617 (1906)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 181 (1914)

maculicornis BRUES — UGANDA
Proc. American Acad. Arts Sci., vol. 61, p. 252 (1926)

melanocerus CAMERON — RHODESIA, TRANSVAAL
Ann. South African Mus., vol. 5, p. 71 (1906)
BRUES, ibid., vol. 19, p. 80 (1924)

melanospilus CAMERON — TRANSVAAL, CAPE PROVINCE
Ann. Transvaal Mus., vol. 2, p. 197 (1911)
BRUES, Ann. South African Mus., vol. 19, p. 80 (1924)

meridianus SZÉPLIGETI — TRANSVAAL
Mitt. Zool. Mus., Berlin, vol. 7, p. 207 (1914)

nigricarpus SZÉPLIGETI — SOMALILAND, KENYA COLONY
Bull. Mus. Hist. Nat. Paris, 1907, p. 36 (1907)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 204 (1914)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 182 (1914)

nigrinervis SZÉPLIGETI — TANGANYIKA TERRITORY, NYASALAND
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 37 (1910)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 6, p. 400 (1908)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 411 (1911)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 255 (1926)

nigrinervis var. **concolor** SZÉPLIGETI — TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 6, p. 400 (1908)

nigronotatus SZÉPLIGETI — SOMALILAND
Mitt. Zool. Mus., Berlin, vol. 7, p. 206 (1914)

nigroörnatus SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 205 (1914)

orientalis SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 206 (1914)

pallidipalpis CAMERON — TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 198 (1911)

pictipennis BRUES — SOUTHERN RHODESIA
Ann. South African Mus., vol. 19, p. 80 (1924)

pleurilineatus CAMERON — TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 197 (1911)

punctipleuris SZÉPLIGETI — TOGO
Mitt. Zool. Mus., Berlin, vol. 7, p. 206 (1914)

reticulator NEES — EGYPT, CANARIES (Europe)
Hymen. Ichneum. affin. Monogr., vol. 1, p. 211 (1834)
MARSHALL, Trans. Ent. Soc. London, 1885, p. 90 (1885)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 281 (1888)

rufifemur Szépligeti — Camerun
Mitt. Zool. Mus., Berlin, vol. 7, p. 206 (1914)

rufoater Wollaston — Madeira
Ann. Mag. Nat. Hist. (3), vol. 1, p. 24 (1858)

ruspolii Mantero — Congo, Somaliland, Tanganyika Territory
Ann. Mus. Civ. Stor. Nat. Genova, (3), vol. 1, p. 413 (1905)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 413 (1914)
Szépligeti, Rés. Sci., Voyage Alluaud, p. 182 (1914)

saturatus Brues — Natal
Proc. American Acad. Arts Sci., vol. 61, p. 250 (1926)

scioënsis Mantero — Somaliland
Ann. Mus. Civ. Stor. Nat. Genova, (3), vol. 1, p. 415 (1905)

semiluteus Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 410 (1911)

semirufus Szépligeti — Tanganyika Territory, Kenya Colony, Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 411 (1911)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 207 (1914)

somaliensis Szépligeti — Somaliland
Mitt. Zool. Mus., Berlin, vol. 7, p. 205 (1914)

striatifrons Cameron — Transvaal
Ann. Transvaal Mus., vol. 2, p. 199 (1911)

surrogatus Schulz — Tanganyika Territory, Natal
Berliner Ent. Zeits., vol. 51, p. 323 (1907)
Cameron, Ann. South African Mus., vol. 5, p. 71 (1906) (*melanocephalus*, nec Cameron, 1887)
Cameron, Ann. Transvaal Mus., vol. 2, p. 196 (1911) (*melanocephalus*)
Cameron, ibid., t.c., p. 196 (1911) (*erythrostomus*)
Szépligeti, Rés. Sci. Voyage Alluaud, p. 183 (1914) (*melanocephalus*)
Brues, Ann. South African Mus., vol. 19, p. 80 (1924) (*melanocephalus*)

testaceus Kriechbaumer — East Africa
Berliner Ent. Zeits., vol. 39, p. 62 (1894) (*Camptocentrus*)

transvaalensis CAMERON SOMALILAND, TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 199 (1911)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 204 (1914)

varicarinatus CAMERON TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 198 (1911)

varinervis CAMERON TRANSVAAL, NATAL
Ann. Transvaal Mus., vol. 2, p. 198 (1911)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 256 (1926)

Scopophthalmus SZÉPLIGETI

Rés. Sci. Voyage Alluaud, p. 182 (1914)
Type: *S. jeanneli* Szépligeti

jeanneli SZÉPLIGETI KENYA COLONY, TANGANYIKA TERRITORY
Rés. Sci. Voyage Alluaud, p. 183 (1914)

Myoporhogas Gen. nov.

SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 183 (1914) (*Microrhogas*, nec Cameron)
Type: *M. ocellaris* Szépligeti

ocellaris Szepligeti Kenya Colony
Rés. Sci. Voyage Alluaud, p. 183 (*Microrhogas*)

Hemigyroneuron BAKER

Philippine Journ. Sci., vol. 12D, p. 322 (1917)
Type: *H. speciosum* Baker

apicale BRUES NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 256 (1926)

Cordylorhogas ENDERLEIN

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 153 (1920)
Brues, Ann. South African Mus., vol. 19, p. 82 (1924) (*Gyroneuron*)
Type: *C. trifasciatus* Enderlein

africanus BRUES ZULULAND
Ann. South African Mus., vol. 19, p. 82 (1924)

trifasciatus ENDERLEIN TRANSVAAL
Arch. Naturg., Jahrg. 84A (1918), Heft. 11, p. 153 (1920)

SUBFAMILY OPIINÆ

Rhinoplus FÖRSTER

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 258 (1862)

Type: *R. fuscipennis* Szépligeti

fulvus BRUES UGANDA

Proc. American Acad. Arts Sci., vol. 61, p. 259 (1926)

fuscipennis SZÉPLIGETI SPANISH GUINEA, BELGIAN CONGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 226 (1914)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 258 (1926)

Opius WESMAEL

Mém. Acad. Sci. Bruxelles, vol. 9, p. 115 (1835)
FORSTER, Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 257 (*Biosteres* and *Diachasma*)
MARSHALL, Trans. Ent. Soc. London, p. 16 (1891)
GAHAN, Proc. U. S. Nat. Mus., vol. 49, p. 65 (1915)

Type: *O. carbonarius* Nees

africanus SZÉPLIGETI TRANSVAAL, CAPE PROVINCE

Boll. Lab. Zool. Gen. Agrar., Portici, vol. 4, p. 346 (1910)
SILVESTRI, Disp. Ent. Agrar., Portici, 1911, p. 442 (1911)
SILVESTRI, Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 111 (1914)
SILVESTRI, ibid., vol. 9, p. 330 (1915)

africanus var. **orientalis** SILVESTRI ERITREA

Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 112 (1914)
SILVESTRI, Bull. Ent. Hawaii, 3, p. 107 (1914)
SILVESTRI, Bull. Lab. Zool. Gen. Agrar., Portici, vol. 9, p. 195 (1914)
SILVESTRI, ibid., vol. 9, p. 330 (1915)

bevisi BRUES NATAL

Proc. American Acad. Arts Sci., vol. 61, p. 261 (1926)

bisulcatus SZÉPLIGETI TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 226 (1914)

carinatus SZÉPLIGETI TANGANYIKA TERRITORY

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 41 (1910) (*Biosteres*)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 191 (1914) (*Biosteres*)

caudatus SZÉPLIGETI NIGERIA

Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 103 (1913) (*Biosteres*)
SILVESTRI, ibid., vol. 8, p. 118 (1914) (*Biosteres*)

cephalotus SZÉPLIGETI TANGANYIKA TERRITORY

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 42 (1910)

circumscriptus SZÉPLIGETI KENYA COLONY, MADAGASCAR

Rés. Sci. Voyage Alluaud, p. 193 (1914)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 428 (1913)

clypeatus BRIDWELL NIGERIA

Proc. Hawaiian Ent. Soc., vol. 4, p. 174 (1919) (*Hedylus*)

concolor SZÉPLIGETI TUNIS

Bull. Soc. Ent. France, 1910, p. 244 (1910)
MARCHAL, C. R. Acad. Paris, vol. 152, p. 215 (1911)
SILVESTRI, Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 97 (1914)

crenulatus SZÉPLIGETI KENYA COLONY

Rés. Sci. Voyage Alluaud, p. 194 (1914)

curiosus SZÉPLIGETI KENYA COLONY

Rés. Sci. Voyage Alluaud, p. 192 (1914)

dacicida SILVESTRI ERITREA

Disp. Ent. Agrar., Portici, 1911, p. 520 (1911)
SILVESTRI, Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 99 (1914)
SILVESTRI, ibid., vol. 9, p. 197 (1914)
SILVESTRI, ibid., t.c., p. 330 (1915)

desideratus BRIDWELL NIGERIA

Proc. Hawaiian Ent. Soc., vol. 4, p. 172 (1919) (*Hedylus*)

dexter SILVESTRI SENEGAL

Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 101 (1914)

efoveolatus SZÉPLIGETI TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 604 (1913)

flavitarsis SZÉPLIGETI ABYSSINIA

Ann. Mus. Nat. Hungarici, vol. 11, p. 605 (1913)

fossulatus SZÉPLIGETI TANGANYIKA TERRITORY

Rés. Sci. Voyage Alluaud, p. 191 (1914)

fullawayi SILVESTRI SENEGAL, NIGERIA, FRENCH GUINEA
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 114 (1914) (*Diachasma*)

fullawayi var. **robustus** SILVESTRI CAMERUN
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 116 (1914) (*Diachasma*)
SILVESTRI, Bull. Ent. Hawaii, 3, p. 109 (1914) (*Diachasma*)

fuscicarpus SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 605 (1913)

fuscitarsis SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 605 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 227 (1914)

giffardii SILVESTRI FRENCH GUINEA
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 113 (1914) (*Hedylus*)

humilis SILVESTRI CAPE PROVINCE
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 106 (1914)

hypopygialis SZÉPLIGETI TANGANYIKA TERRITORY, MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 428 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 226 (1914)

inconsuetus SILVESTRI NIGERIA
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 107 (1914)

inquirendus SILVESTRI CAMERUN
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 109 (1914)

liogaster SZÉPLIGETI TANGANYIKA TERRITORY
Rés. Sci. Voyage Alluaud, p. 192 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 227 (1914)

lounsburyi SILVESTRI TRANSVAAL
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 100 (1914)

luteus KRIECHBAUMER NATAL
Berliner Ent. Zeits., vol. 39, p. 314 (1894)

major SZÉPLIGETI KENYA COLONY
Rés. Sci., Voyage Alluaud, p. 193 (1914)

niger SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 604 (1913) (*Biosteres*)

nigromaculatus SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 227 (1914)

niloticus SCHMIEDEKNECHT EGYPT
Termes. Füzetek, vol. 23, p. 247 (1900)
palpalis SZÉPLIGETI ASHANTILAND
Termes. Füzetek, vol. 25, p. 82 (1902)
peregrinus SZÉPLIGETI KILIMANDJARO, 12,000 FT.
Mitt. Zool. Mus., Berlin, vol. 7, p. 227 (1914)
perproximus SILVESTRI DAHOMEY
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 103 (1914)
perproximus var. **modestior** SILVESTRI GOLD COAST, NIGERIA
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 8, p. 104 (1914)
punctulatus SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 227 (1914)
pusillus SZÉPLIGETI MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 427 (1913)
sulphureus SZÉPLIGETI MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 428 (1913)
terebrator SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 228 (1914)
testaceus SZÉPLIGETI KILIMANDJARO, 12,000 FT.
Mitt. Zool. Mus., Berlin, vol. 7, p. 225 (1914) (*Biosteres*)
vittator BRUES NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 260 (1926)

Eurytenes FÖRSTER

Verh. Naturh. Ver. preuss. Rheinlande, vol. 19, p. 250 (1862)
Type: *E. anbormius* Wesmael

cingulatus SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 606 (1913)
luteipes SZÉPLIGETI KENYA COLONY
Rés. Sci., Voyage Alluaud, p. 194 (1914)
melanosoma SZÉPLIGETI KENYA COLONY
Rés. Sci., Voyage Alluaud, p. 195 (1914)
persimilis SZÉPLIGETI TANGANYIKA TERRITORY
Ann. Mus. Nat. Hungarici, vol. 11, p. 606 (1913)

pusillus Szépligeti — Tanganyika Territory

Ann. Mus. Nat. Hungarici, vol. 11, p. 606 (1913)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 226 (1914)

testaceipes Szépligeti — Tanganyika Territory

Ann. Mus. Nat. Hungarici, vol. 11, p. 607 (1913)

Sulydus Buysson

Ann. Soc. Ent. France, vol. 66, p. 354 (1897)

Type: *S. marshalli* Buysson

marshalli Buysson — Transvaal

Ann. Soc. Ent. France, vol. 66, p. 354, pl. 11, figs. 1, 1b (1897)

Subfamily HELCONINÆ

Helcon Nees

Mag. Gesellsch. naturf. Freunde, Berlin, vol. 6, p. 216 (1814)
Förster, Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 255 (1862) (*Gymnoscelis*)

Type: *H. tardator* Nees

tardator Nees — Algeria (Europe)

Magaz Gesellsch. naturf. Fruende, Berlin, vol. 6, p. 218 (1814)
Nees, Hymen. Ichneum. affin Monogr., vol. 1, p. 228 (1834)
Lucas, Explor. Sci. Algérie, Zool., vol. 3, p. 337 (1846)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 225 (1893) (*Gymnoscelis*)

Aspicolpus Wesmael

Nouv. Mém. Acad. Sci., Bruxelles, vol. 11, p. 158 (1838)

Type: *A. carinator* Nees

grandior Brues — Rhodesia

Proc. American Acad. Arts Sci., vol. 61, p. 263 (1926)

pictipennis Brues — British Southwest Africa

Proc. American Acad. Arts Sci., vol. 61, p. 264 (1926)

riggenbachi Szépligeti — Senegal

Mitt. Zool. Mus., Berlin, vol. 7, p. 223 (1914)

Neohelcon Szépligeti

Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 427 (1913)

Type: *N. braconinus* Szépligeti

braconinus Szépligeti — Madagascar
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 427 (1913)

Pseudohelcon Szépligeti

Mitt. Zool. Mus., Berlin, vol. 7, p. 223 (1914)
Type: *P. tessmanni* Szépligeti

distanti Turner — Transvaal
Ann. Mag. Nat. Hist. (9), vol. 10, p. 278 (1922)

tessmanni Szépligeti — Spanish Guinea, Tanganyika Terr.
Mitt. Zool. Mus., Berlin, vol. 7, p. 223 (1914)

Rinamba Cameron

Ann. Soc. Ent. Belgique, vol. 56, p. 375 (1912)
Type: *R. opacicollis* Cameron

opacicollis Cameron — Belgian Congo
Ann. Soc. Ent. Belgique, vol. 56, p. 375 (1912)

Stirostoma Cameron

Ann. Soc. Ent. Belgique, vol. 56, p. 376 (1912)
Type: *S. longicornis* Cameron

longicornis Cameron — Belgian Congo
Ann. Soc. Ent. Belgique, vol. 56, p. 376 (1912)

Subfamily DIOSPILINÆ

Neodiospilus Szépligeti

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 415 (1911)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 224 (1914)
Type: *N. flavipes* Szépligeti

baumanni Szépligeti — Togo, Tanganyika Territory
Mitt. Zool. Mus., Berlin, vol. 7, p. 224 (1914)

flavipes Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 416 (1911)

terebrator Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 416 (1911)

zenkeri Szépligeti — Camerun
Mitt. Zool. Mus., Berlin, vol. 7, p. 224 (1914)

Eudiospilus Szépligeti

Mitt. Zool. Mus. Berlin, vol. 7, p. 225 (1914)

Type: *E. conradti* Szépligeti

conradti Szépligeti — Camerun

Mitt. Zool. Mus., Berlin, vol. 7, p. 225 (1914)

tricolor Szépligeti — Camerun

Mitt. Zool. Mus., Berlin, vol. 7, p. 225 (1914)

Subfamily CHELONINÆ

Chelonus Panzer

Krit. Rev., vol. 2, p. 99 (1806)

Type: *C. oculator* Fabricius

bifoveolatus Szépligeti — Belgian Congo, Tanganyika Terr.

Mitt. Zool. Mus., Berlin, vol. 7, p. 208 (1914)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 414 (1914)

capensis Cameron — Cape Province

Zeits. Naturwiss., vol. 81, p. 440 (1909)

erythrogaster Lucas — Algeria

Explor. Sci. Algérie, Zool., vol. 3, p. 340 (1846)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 343 (1889)

erythropus Cameron — Cape Province

Ann. South African Mus., vol. 5, p. 33 (1906)

inanitus Linné — Algeria (Europe)

Syst. Nat., Ed. 12a, vol. 1, p. 919 (1767) (*Cynips*)
Nees, Hymen. Ichneum. affin. Monogr., vol. 1, p. 209 (1834)
Marshall, Trans. Ent. Soc. London, 1885, p. 118 (1885)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 330 (1888)

pilosulus Szépligeti — Nyasaland

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 412 (1911)

robertianus Cameron — Cape Province

Rec. Albany Mus., Grahamstown, vol. 1, p. 110 (1904)

rufoscapus Cameron — Transvaal

Ann. Transvaal Mus., vol. 2, p. 200 (1911)

tettensis Gerstaecker — Mozambique

Ber. Akad. Wiss. Berlin, p. 264 (1858)

vaalensis CAMERON — TRANSVAAL
Ann. South African Mus., vol. 5, p. 34 (1906)

Chelonella SZÉPLIGETI

Ann. Mus. Nat. Hungarici, vol. 6, p. 403 (1908)
Type: *C. basalis* Curtis

curvimaculata CAMERON — NYASALAND, CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 34 (1906) (*Chelonus*)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 411 (1911)
BRUES, Ann. South African Mus., vol. 19, p. 105 (1924)

hungarica SZÉPLIGETI — ALGERIA (Europe)
Termes. Füzetek, vol. 19, p. 176, 237 (1896) (*Chelonus*)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 5, p. 160 (1898) (*Chelonus*)

nigricornis SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 208 (1914)

ruficornis SZÉPLIGETI — PORTUGUESE EAST AFRICA
Ann. Mus. Nat. Hungarici, vol. 11, p. 601 (1913)

Pachychelonus BRUES

Ann. South African Mus., vol. 19, p. 107 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 271 (1926)
Type: *P. fulviventris* Brues

fulviventris BRUES — NORTHERN RHODESIA, NATAL
Ann. South African Mus., vol. 19, p. 107 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 271 (1926)

Minanga CAMERON

Ann. South African Mus., vol. 5, p. 30 (1906)
BRUES, ibid., vol. 19, p. 106 (1924)
Type: *M. serrata* Cameron

bimaculata CAMERON — TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 202 (1911)

flavipes CAMERON — CAPE PROVINCE
Zeits. Naturwiss., vol. 81, p. 437 (1909)

serrata CAMERON — CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 31 (1906)
CAMERON, Zeits. Naturwiss., vol. 81, p. 437 (1909)

Odontosphæropyx CAMERON

Zeits. Naturwiss., vol. 81, p. 436 (1909)
Type: *O. ruficeps* Cameron

ruficeps CAMERON — CAPE PROVINCE
Zeits. Naturwiss., vol. 81, p. 436 (1909)

Acanthochelonus BRUES

Proc. American Acad. Arts Sci., vol. 61, p. 271 (1926)
Type: *A. taurus* Brues

taurus Brues — KATANGA, BELGIAN CONGO
Proc. American Acad. Arts Sci., vol. 61, p. 272 (1926)

Ascogaster WESMAEL

Nouv. Mém. Acad. Sci. Bruxelles, vol. 9, p. 226 (1835)
Type: *A. instabilis* Wesmael

bipustulatus BRUES — ZULULAND
Ann. South African Mus., vol. 19, p. 105 (1924)

maculata WOLLASTON — MADEIRA
Ann. Mag. Nat. Hist. (3), vol. 1, p. 24 (1858)

punctata SZÉPLIGETI — KENYA COLONY
Rés. Sci. Voyage Alluaud, p. 186 (1914)

rubripes LUCAS — ALGERIA
Explor. Sci. Algérie, Zool., vol. 3, p. 339 (1846)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 378 (1889)

Sigalphus LATREILLE

Hist. Nat. Crust. et Ins., vol. 3, p. 329 (1802)
ILLIGER, Rossi, Faun. Etrusc., 2nd. Edit., vol. 2, p. 54 (1807) (*Sphæropyx*)
Type: *S. irrorator* Fabricius

fulvus BRUES — NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 269 (1926)

neavei TURNER — NORTHEASTERN RHODESIA
Ann. Mag. Nat. Hist. (8), vol. 20, p. 246 (1917) (*Sphæropyx*)

Phanerotoma WESMAEL

Nouv. Mém. Acad. Sci. Belgique, vol. 11, p. 165 (1838)

Type: *P. dentata* Nees

curvicarinata CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 204 (1911)

curvimaculata CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 203 (1911)

decorata SZÉPLIGETI SOUTHERN SOMALILAND

Mitt. Zool. Mus., Berlin, vol. 7, p. 209 (1914)

dubia BINGHAM MASHONALAND

Trans. Ent. Soc. London, 1902, p. 546, pl. 18, fig. 69 (1902)

leucobasis KRIECHBAUMER TOGO, CAMERUN, EAST AFRICA

Berliner Ent. Zeits., vol. 39, p. 62 (1894)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 38 (1910)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 425 (1913)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 187 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 209 (1914)

major BRUES KENYA COLONY

Proc. American Acad. Arts Sci., vol. 61, p. 266 (1926)

nigriceps SZÉPLIGETI TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 209 (1914)

ocularis KOHL SOKÓTRA

Denkschr. Akad. Wiss. Wien, vol. 71, p. 292 (1907)

ornatula BRUES NATAL

Proc. American Acad. Arts Sci., vol. 61, p. 267 (1926)

pallidipes CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 203 (1911)

planifrons NEES ALGERIA (Europe)

Magaz. Ges. naturf. Freunde Berlin, vol. 7, p. 259 (1813) (*Sigalphus*
NEES, Hymen. Ichneum. affin. Monogr., vol. 1, p. 281 (1834) (*Chelonus*)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 4, p. 381 (1889)

pygmæa SZÉPLIGETI TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 602 (1913)

sareptana Kohl — Palestine
Denkschr. Akad. Wiss. Wien, vol. 71, p. 293 (1907)

saussurei Kohl — Madagascar
Denkschr. Akad. Wiss. Wien, vol. 71, p. 293 (1907)

uniformis Brues — Natal
Proc. American Acad. Arts Sci., vol. 61, p. 268 (1926)

variegata Szépligeti — Kenya Colony
Rés. Sci. Voyage Alluaud, p. 187 (1914)

Phanerotomella Szépligeti

Termes. Füzetek, vol. 23, p. 59 (1900)
Type: *P. longipes* Szépligeti

lutea Szépligeti — Kenya Colony
Voy. Rothschild. E. Afr. Anim. Art., pt. 2, p. 907 (1922).

Subfamily TRIASPIDINÆ

(Sigalphinæ)

Neoacampsis Szépligeti

Mitt. Zool. Mus., Berlin, Vol. 7, p. 210 (1914)
Type: *N. gracilipes* Szépligeti

gracilipes Szépligeti — Guinea
Mitt. Zool. Mus., Berlin, Vol. 7, p. 210 (1914)

Triaspis Haliday

Ent. Mag., Vol. 3, p. 123 (1835)
Viereck, Proc. U. S. Nat. Mus., vol. 42, p. 628 (1912)
Sigalphus of recent authors, not Latreille
Type: *T. caudatus* Nees

daci Szépligeti — Transvaal
Boll. Lab. Zool. Gen. Agrar. Portici, vol. 5, p. 223 (1911) (*Sigalphus*)
Silvestri, ibid., vol. 8, p. 121 (1914) (*Sigalphus*)
Silvestri, ibid., l.c. p. 330 (1915) (*Sigalphus*)

emarginatus Szépligeti — Tanganyika Territory
Mitt. Zool. Mus., Berlin Vol. 7, p. 207 (1914) (*Sigalphus*)

floricola Wesmael ALGIERS (Europe)

Nouv. Mém. Acad. Sci., Bruxelles, vol. 9, p. 208 (1835) (*Sigalphus*)
MARSHALL, Trans. Ent. Soc. London, 1885, p. 106 (1885) (*Sigalphus*)
MARSHALL, Spéc. Hymén. Europe, vol. 4, p. 319 (1888) (*Sigalphus*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 6, p. 402 (1908) (*Sigalphus*)

pygmæus SZÉPLIGETI TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 601 (1913) (*Sigalphus*)

simplicifrons Brues TRANSVAAL

Ann. South African Mus., vol. 19, p. 109 (1924)

testaceus SZÉPLIGETI TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 207 (1914) (*Sigalphus*)

Foersteria SZÉPLIGETI

Wiener Ent. Zeits., vol. 15, p. 148 (1896)

Type: *F. flavipes* Szépligeti

nitida Cameron TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 204 (1911)

Allodorus FÖRSTER

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 242 (1862)

Type: *A.* (*Sigalphus*) *semirugosus* Nees

major BEQUAERT DAHOMEY

Bull. Soc. Ent. France, 1916, p. 103 (1916)

SUBFAMILY MACROCENTRINÆ

Amicrocentrum Schulz

Zool. Ann., vol. 4, p. 88 (1911)
Szépligeti, Gen. Insect., fasc. 22, p. 145 (1904) (*Megacentrus*, non Heer)
CAMERON, Ann. Soc. Ent. Belgique, vol. 56, p. 370 (1912) (*Eiolo*)
BRUES, Proc. American Acad. Arts. Sci., vol. 61, p. 274 (1926)

Type: *A.* (*Megacentrus*) *concolor* Szépligeti

concolor SZÉPLIGETI KENYA COLONY, SO. ETHIOPIA, CONGO

Gen. Insect., fasc. 22, p. 146 (1904)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 41 (1910) (*Megacentrus*)

SZÉPLIGETI, Wiss. Ergebn. deutsch Zentral-Afrika Exped. 1907–08, vol. 3, p. 415 (1911) (*Megacentrus*)
SZÉPLIGETI, Mitt. Zool. Mus. Berlin, vol. 7, p. 221 (1914)
ENDERLEIN, Arch. Naturg., Jahrg 84A (1918), Heft. 11, p. 213 (1920) (*Megacentrus*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 274 (1926)

curvinervis CAMERON BELGIAN CONGO
Ann. Soc. Ent. Belgique, vol. 56, p. 372 (1912) (*Eiolo*)

Macrocentrus CURTIS

Entom. Mag., vol. 1, p. 187 (1833)
Type: *M. thoracicus* Nees.

annulicornis CAMERON TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 211 (1911)

capensis CAMERON CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 30 (1906)
BRUES, ibid., vol. 19, p. 63 (1924)

fuscicornis SZÉPLIGETI TANGANYIKA TERRITORY
Rés. Sci. Voyage Allauud, p. 193 (1914)

latisulcatus CAMERON TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 210 (1911)

luteus CAMERON TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 210 (1911)

luteus SZÉPLIGETI CAMERUN, TANGANYIKA TERR., COMORO ISL.
Wiss. Ergebn. deutsch. Zentral Afrika Exped. 1907–08, vol. 3, p. 415 (1911)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 427 (1913)
SZÉPLIGETI, Mitt. Zool. Mus. Berlin, vol. 7, p. 222, (1914)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 190 (1914)

nigriceps SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, Vol. 7, p. 222 (1914)

nigroörnatus CAMERON TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 211 (1911)

oculatus SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 17, p. 221 (1914)

pallidistigma CAMERON UGANDA, TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 210 (1911) (*pallidistigmas*)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 190 (1914)

rugulosus SZÉPLIGETI TOGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 222 (1914)

sulphureus SZÉPLIGETI BRITISH SOUTHWEST AFRICA

Mitt. Zool. Mus., Berlin, vol. 7, p. 222 (1914)

testaceipes SZÉPLIGETI SPANISH GUINEA

Mitt. Zool. Mus., Berlin, vol. 7, p. 222 (1914)

Paniscozele ENDERLEIN

Arch. Naturg., Jahrg 84A (1918), Heft 11, p. 214 (1920)
Type: *P. sumatrana* Enderlein

straminea ENDERLEIN TANGANYIKA TERRITORY

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 215 (1920)

Zele CURTIS

British Entom., Vol. 9, p. 415 (1832)
Type: *Z. testaceator* Curtis

maculiceps CAMERON BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 372 (1912)

nigricornis WALKER ARABIA, EGYPT, KENYA COLONY, TANGANYIKA TERR.

List. Hymen. Egypt, p. 5 (1871) (*Phylax*)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 41 (1910)
SZÉPLIGETI, Mitt. Zool. Mus. Berlin, vol. 7, p. 223 (1914)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 191 (1914)

somaliensis SZÉPLIGETI SOMALILAND

Mitt. Zool. Mus., Berlin, vol. 7, p. 223 (1914)

SUBFAMILY CALYPTINÆ

Brachistes WESMAEL

Nouv. Mém. Acad. Sci., Bruxelles, vol. 9, p. 109 (1835)
Type: *B.* (*Bracon*) *ruficoxis* Wesmael

cruentatus REINHARD — ALGERIA (Europe)

Berliner Ent. Zeits., vol. 11, p. 370 (1867) (*Calyptus*)
MARSHALL, Spéc. Hymén. Europe et Algérie, vol. 5bis, p. 150 (1893) (*Calyptus*)
SZÉPLIGETI, Genera Insect., fasc. 22, p. 135 (1905) (*Calyptus*)

orientalis SZÉPLIGETI — KENYA COLONY

Voyage Alluaud, Hymén, p. 189 (1914) (*Calyptus*)

Eubazus NEES

Mag. Gesellsch. naturf. Freunde, Berlin, vol. 6, p. 214 (1814)
NEES, Hym. Ichneum. affin. Monogr., vol. 1, p. 214 (1834) (*Eubadizon*)

Type: *E. pallipes* Nees

westermanni ENDERLEIN — SPANISH GUINEA

Arch. Naturg., Jahrg. 78A, Heft 2, p. 39 (1912) (*Eubadizon*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 220 (1914) (*Eubadizon*)

Clotildea SZÉPLIGETI

Ann. Soc. Ent. Belgique, vol. 58, p. 118 (1914)

Type: *C. lucida* Szépligeti

lucida SZÉPLIGETI — FRENCH CONGO

Ann. Soc. Ent. Belgique, vol. 58, p. 118 (1914)

SUBFAMILY BLACINÆ

Cyclocormus CAMERON

Ann. Transvaal Mus., vol. 2, p. 209 (1911)

Type: *C. luteus* Cameron

luteus CAMERON — TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 209 (1911)

Blacus NEES

Nov. Act. Acad. Nat. Curios., vol. 9, p. 306 (1818)

Type: *B. humilis* Nees

natalensis BRUES — NATAL

Proc. American Acad. Arts Sci., vol. 61, p. 277 (1926)

SUBFAMILY LEIOPHRONINÆ

Leiophron NEES

Nov. Act. Acad. Nat. Curios., vol. 9, p. 303 (1818)

punctatus BRUES — NATAL

Proc. American Acad. Arts Sci., vol. 61, p. 278 (1926)

Centistes HALIDAY

Ent. Mag., vol. 2, p. 462 (1836)

Type: *C. cuspidatus* Haliday

flavipes SZÉPLIGETI — KENYA COLONY

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 416 (1911)

Centistina ENDERLEIN

Arch. Naturg., vol. 78A, Heft 2, p. 40 (1912)

Type: *C. longicornis* Enderlein

longicornis ENDERLEIN — MADAGASCAR

Arch. Naturg., Jahrg 78A, Heft 2, p. 40 (1912)

SUBFAMILY CARDIOCHILINÆ

Cardiochiles Nees

Hymen. Ichneum. affin. Monogr., vol. 1, p. 224 (1834)
CAMERON, Rec. Albany Mus., Grahamstown, vol. 1, p. 169 (1905) (*Schönlandella*)
Cameron, Spolia Zeylandia, vol. 3, p. 81 (1905) (*Ernestiella*)
Turner, Ann. Mag. Nat. Hist. (9), vol. 1, p. 52 (1918)

Type: *E. saltator* Fabricius

angustifrons BRUES — NATAL

Ann. South African Mus., vol. 19, p. 94 (1924)

ater SZÉPLIGETI — BELGIAN CONGO

Rev. Zool. Africaine, vol. 3, p. 420 (1914)

bequaerti BRUES — KATANGA, BELGIAN CONGO

Proc. American Acad. Arts Sci., vol. 61, p. 282 (1926)

bifoveatus CAMERON — BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 380 (1912) (*Cardiochelis*)

enderleini SZÉPLIGETI — TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 6, p. 423 (1908)

forticarinatus CAMERON CAPE PROVINCE

Zeits. Naturwiss., vol. 81, p. 445 (1909) (*Cardiochelis*)

fossatus BRUES NATAL

Ann. South African Mus., vol. 19, p. 97 (1924)

BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 283 (1926)

fulviventris CAMERON CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 40 (1906) (*Schönlandella*)
CAMERON, Trans. South African Philos. Soc., vol. 16, p. 331 (1906)
BRUES, Ann. South African Mus., vol. 19, p. 93 (1924)

latifrons BRUES CAPE PROVINCE

Ann. South African Mus., vol. 19, p. 93 (1924)

longiceps ROMAN EQUATORIAL AFRICA

Ent. Tidsker., vol. 31, p. 116 (1910)
SILVESTRI, Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 103 (1913)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 419 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 221 (1914)
SZÉPLIGETI, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 154 (1915)

longipennis BRUES BELGIAN CONGO, ZULULAND

Ann. South African Mus., vol. 19, p. 98 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 284 (1926)

minor SZÉPLIGETI TANGANYIKA TERRITORY

Rés. Sci. Voyage Alluaud, p. 189 (1914)

niger SZÉPLIGETI SPANISH GUINEA, BELGIAN CONGO

Mitt. Zool. Mus., Berlin, vol. 7, p. 221 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 420 (1914)

nigricollis CAMERON BELGIAN CONGO, CAPE PROVINCE

Rec. Albany Mus., Grahamstown, vol., p. 171 (1905) (*Schönlandella*)
CAMERON, Trans. South African Philos. Soc., vol. 16, p. 331 (1906)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 420 (1914)

nigromaculatus CAMERON NYASALAND, NATAL, CAPE PROVINCE

Rec. Albany Mus., Grahamstown, vol. 1, p. 170 (1905) (*Schönlandella*)

CAMERON, Trans. South African Philos. Soc., vol. 16, p. 331 (1906)
SZÉPLIGETI, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 415 (1911)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 283 (1926)

nitidus Brues — Nomaqualand

Ann. South African Mus., vol. 19, p. 96 (1924)

pulchripes Szépligeti — Spanish Guinea, Belgian Congo

Mitt. Zool. Mus., Berlin, vol. 7, p. 221 (1914)
Szepligeti, Rev. Zool. Africaine, vol. 3, p. 420 (1914)

punctatus Szépligeti — Belgian Congo, Tanganyika Terr., Zanzibar

Ann. Mus. Nat. Hungarici, vol. 11, p. 603 (1913)
Szépligeti, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 427 (1913)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 419 (1914)

rufomaculatus Cameron — Cape Province

Zeits. Naturwiss., vol. 81, p. 446 (1909) (*Cardiochelis*)

scapularis Brues — Cape Province

Proc. American Acad. Arts Sci., vol. 61, p. 279 (1926)

striatifrons Brues — Natal

Proc. American Acad. Arts Sci., vol. 61, p. 281 (1926)

striatus Brues — Transvaal, Natal, Cape Province

Ann. South African Mus., vol. 19, p. 95 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 282 (1926)

tegularis Brues — Kenya Colony, Natal

Ann. South African Mus., vol. 19, p. 100 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 283 (1926)

testaceipes Cameron — Belgian Congo, Southern Rhodesia

Ann. South African Mus., vol. 5, p. 39 (1906) (*testaceus*, non Kriechbaumer)
Cameron, Trans. South African Philos. Soc., vol. 16, p. 331 (1906)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 420 (1914)
Brues, Ann. South African Mus., vol. 19, p. 93 (1924)

testaceus Kriechbaumer — Camerun, Nyasaland, Somaliland, Tanganyika Terr.

Berliner Ent. Zeits., vol. 39, p. 62 (1894)
Szépligeti, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 41 (1910)
Szépligeti, Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 415 (1911)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 221 (1914)

trimaculatus CAMERON — TANGANYIKA TERRITORY, CAPE PROVINCE

Rec. Albany Mus., Grahamstown, Vol. 1 p 171 (1905) (*Schönlandella*)
CAMERON, Trans. South African Philos. Soc., vol. 16, p. 331 (1906)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 6, p. 423 (1908)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 221 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 420 (1914)

variegatus SZÉPLIGETI — TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 603 (1913)

xanthocarpus SZÉPLIGETI — TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 604 (1913)

SUBFAMILY MIMAGATHIDINÆ

Stantonia ASHMEAD

Proc. U. S. Nat. Mus., vol. 28, p. 146 (1904)
Type: *S. flava* Ashmead

algirica SZÉPLIGETI — ALGERIA

Ann. Mus. Nat. Hungarici, vol. 6, p. 427 (1908) (*Microtypus*)

hammersteini ENDERLEIN — TANGANYIKA TERRITORY

Stettiner Ent. Zeitg., vol. 69, p. 110 (1908)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 220 (1914)

testacea SZÉPLIGETI — TANGANYIKA TERRITORY.

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 40 (1910)

SUBFAMILY AGATHIDINÆ

Bæognatha KOKUJEW

Horæ Soc. Ent. Rossicæ, vol. 36, p. 243 (1903)
Type: *B. turanica* Kokujew

canariensis SZÉPLIGETI — CANARIES

Ann. Mus. Nat. Hungarici, vol. 6, p. 411 (1908)

Orgilus HALIDAY

Ent. Mag., vol. 1, p. 262 (1833)
Type: *O. obscurator* Nees

apostolicus TURNER — CAPE PROVINCE

Ann. Mag. Nat. Hist. (9), vol. 10, p. 277 (1922)

bifasciatus TURNER — CAPE PROVINCE
Ann. Mag. Nat. Hist. (9), vol. 10, p. 276 (1922)

parcus TURNER — CAPE PROVINCE
Ann. Mag. Nat. Hist. (9), vol. 10, p. 276 (1922)

pusillus SZÉPLIGETI — MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 426 (1913)
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 152 (1915)

Pseudocremnops SZÉPLIGETI

Ergebn 2ten. Zent.-Afrika Exped., vol. 1 p. 152 (1915)
Type: *P. atripennis* Szépligeti

atripennis SZÉPLIGETI — SPANISH GUINEA, CAMERUN, BELGIAN CONGO
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 152 (1915)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 212 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 416 (1914)

Megagathis KRIECHBAUMER

Berliner Ent. Zeits., vol. 39, p. 311 (1894)
Type: *M. nataliensis* Kriechbaumer

africana SZÉPLIGETI — TOGO, SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 212 (1914)

borealis SZÉPLIGETI — TRIPOLIS
Mitt. Zool. Mus. Berlin, vol. 7, p. 212 (1914)

costata BRULLÉ — BOURBONIA, TOGO
Hist. Nat. Ins. Hymen., vol. 4, p. 492 (1846) (*Agathis*)

flagellaris SZÉPLIGETI — BELGIAN CONGO
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 151 (1915)

fülleborni SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 212 (1914)

nataliensis KRIECHBAUMER — ZULULAND, NATAL
Berliner Ent. Zeits., vol. 39, p. 312 (1894)
BRUES, Ann. South African Mus., vol. 19, p. 144 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 285 (1926)

persimilis SZÉPLIGETI — EQUATORIAL AFRICA
Ergebn. 2ten. Zent-Afrika Exped., vol. 1, p. 151 (1915)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 212 (1914)

pulchricornis SZÉPLIGETI BELGIAN CONGO
Rev. Zool. Africaine, vol. 3, p. 415 (1914)

rufigaster SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 212 (1914)

schoutedeni SZÉPLIGETI BELGIAN CONGO, NATAL
Rev. Zool. Africaine, vol. 3, p. 415 (1914)
BRUES, Proc. American Acad. Arts & Sci., vol. 61, p. 285 (1926)

stellata SZÉPLIGETI BELGIAN CONGO, CAMERUN
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 151 (1915)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 211 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 415 (1914)

testacea CAMERON SEYCHELLES IS.
Trans. Linn. Soc. London, Zool. (2), vol. 12, p. 82 (1907)

variabilis SZÉPLIGETI BELGIAN CONGO, SPANISH GUINEA
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 150 (1915)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 212 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 415 (1914)

Cænophylax Schulz

Zool. Ann., vol. 4, p. 88 (1911)
ASHMEAD, Proc. U. S. Nat. Mus., vol. 23, p. 119 (1900) (*Neophylax*, nec McLachlan)
ROHWER, Proc. Ent. Soc., Washington, vol. 17, p. 56 (1915) (*Neophylax*)

snyderi ROHWER CONGO
Proc. Ent. Soc. Washington, vol. 17, p. 56 (1915)

Camptothlipsis ENDERLEIN

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 166 (1920)

costalis ENDERLEIN TRANSVAAL
Arch. Naturg., Jahrg. 84A (1918,) Heft 11, p. 167 (1920)

perula ENDERLEIN ERITREA
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 167 (1920)

Hyrtanommatium ENDERLEIN

Arch. Naturg., Jahrg 84A (1918), Heft 11, p. 165 (1920)
BRUES, Proc. American Acad. Arts & Sci., vol. 61, p. 285 (1926)
Type: *H. crassum* Enderlein

crassum ENDERLEIN GOLD COAST
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 166 (1920)

terebrator BRUES NATAL
Ann. South African Mus., vol. 19, p. 86 (1924) (*Eugathis*)
BRUES, Proc. American Acad. Arts & Sci., vol. 61, p. 285 (1926)

Troticus Brullé

Hist. Nat. Ins. Hymén., vol. 4, p. 508 (1846)
Type: *T. ovatus* Brullé

ovatus BRULLÉ CAPE PROVINCE
Hist. Nat. Ins. Hymén., vol. 4, p. 509 (1846)

Euagathis SZÉPLIGETI

Termes. Füzetek, vol. 23, p. 62 (1900)
Type: *E. bifasciata* Szépligeti

albotarsus SZÉPLIGETI CAMERUN
Ark. Zool., vol. 2, No. 14, p. 10 (1905)

annulitarsis SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 215 (1914)

atripennis SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 215 (1914)

ecostatus SZÉPLIGETI CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 216 (1914)

hemixanthopterus SZÉPLIGETI FRENCH SOMALILAND
Ann. Soc. Ent. Belgique, vol. 58, p. 116 (1914)

levis SZÉPLIGETI KENYA COLONY
Mitt. Zool. Mus., Berlin, vol. 7, p. 216 (1914)

politus SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 216 (1914)

rufithorax SZÉPLIGETI TANGANYIKA TERRITORY
Rés. Sci. Voyage Alluaud, p. 187 (1914)

suturalis SZÉPLIGETI MOZAMBIQUE
Mitt. Zool. Mus., Berlin, vol. 7, p. 217 (1914)

transitor SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 216 (1914)

Macroagathis Szépligeti

Ann. Mus. Nat. Hungarici, vol. 6, p. 418 (1908)

Type: *M. levis* Szépligeti

levis Szépligeti — Tanganyika Territory
Ann. Mus. Nat. Hungarici, vol. 6, p. 418 (1908)

Cremnops Förster

Verh. naturf. Ver. preuss. Rheinlande, vol. 19, p. 246 (1862)

Type: *C. desertor* Linn.

africana Szépligeti — Tanganyika Territory, Camerun
Ann. Mus. Nat. Hungarici, vol. 3, p. 51 (1905)
Szépligeti, ibid., vol. 6, p. 419 (1908)

atripennis Szépligeti — Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 211 (1914)

costata Brullé — Sierra Leone, Tanganyika Terr., Reunion
Hist. Nat. Ins. Hymén. vol. 4, p. 492 (1846) (*Agathis*)
Kriechbaumer, Berliner Ent. Zeits., vol. 39, p. 63 (1894) (*anomala*)
Szépligeti, Ann. Mus. Nat. Hungarici, vol. 6, p. 419 (1908)
Roman, Ent. Tidskr., vol. 31, p. 120 (1910)
Szépligeti, Wiss. Ergebn, Kilimandjaro-Meru Exped., vol. 2, p. 38 (1910)

elegantissima Szépligeti — Tanganyika Territory
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 38 (1910)

monochroa Szépligeti — Tanganyika Territory
Ann. Mus. Nat. Hungarici, vol. 11, p. 603 (1913)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 211 (1914)

obsolescens Brues — Zululand
Ann. South African Mus., vol. 19, p. 91 (1924)

persimilis Szépligeti — French Congo
Ann. Soc. Ent. Belgique, vol. 58, p. 116 (1914)

pulchripennis Szépligeti — Camerun
Ark. Zool. vol. 2, No. 14, p. 9 (1905)

rufigaster Szépligeti — Tanganyika Territory
Rés. Sci. Voyage Alluaud, p. 188 (1914)

rufitarsis Szépligeti — French Guinea
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 103 (1913)

schubotzi Szépligeti — Belgian Congo
Ergebn. 2 ten. Zent.-Afrika Exped., vol. 1, p. 150 (1915)
variabilis Szépligeti — French Guinea
Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7 p. 103 (1914)
zululandensis Brues — Zululand
Ann. South African Mus., vol. 19, p. 90 (1924)

Mesoagathis Cameron

Rec. Albany Mus. Grahamstown, vol. 1, p. 172 (1905)
Type: *M. fuscipennis* Cameron

fuscipennis Cameron — Cape Province
Rec. Albany Mus., Grahamstown, vol. 1, p. 172 (1905)

Adiathlipsis Enderlein

Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 194 (1920)
Type: *A. fasciata* Enderlein

fasciata Enderlein — Madagascar
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 195 (1920)

Disophrys Förster

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 246 (1862)
Kriechbaumer, Berliner Ent. Zeits., vol. 39, p. 65 (1894) (*Pseudagathis*)
Kriechbaumer, *ibid.*, *t.c.* p. 312 (1894) (*Brachyrhopalum*)
Cameron, Rec. Albany Mus. Grahamstown, vol. 1, p. 157 (1905) (*Xanthomicrodus*)

albotarsus Szépligeti — Belgian Congo
Rev. Zool. Africaine, vol. 3, p. 416 (1914)
atrocarpa Szépligeti — Spanish Guinea
Mitt. Zool. Mus., Berlin, vol. 7, p. 213 (1914)
blandula Enderlein — Camerun
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 186 (1920)
cæsia Klug — Algeria (Europe)
Watl; Reise d. Tirol, p. 89 (1835) (*Agathis*)
Marshall, Spéc. Hymén. Europe., vol. 4, p. 574 (1890) (*cæsus*)
Szépligeti, Termes. Füzetek, vol. 19, p. 308, 377 (1896)
Kriechbaumer, Ent. Nachr., Jahrg 24, p. 182 (1898)

cæsia, var. **rubinotum** STRAND. ALGERIA
Entom. Zeits. Stuttgart, vol. 24, p. 219 (1910)

calabarica KRIECHBAUMER OLD CALABAR, SPANISH GUINEA
Entom. Nachrich., vol. 24, p. 65 (1898)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 214 (1914)

capensis SZEPLIGETI CAPE PROVINCE
Mitt. Zool. Mus., Berlin, vol. 7, p. 214 (1914)

dichroa Brullé SOUTH AFRICA
Hist. Nat. Ins. Hymén., vol. 4, p. 485 (1846) (*Agathis*)
CAMERON, Rec. Albany Mus., Grahamstown, vol. 1, p. 158 (1905) (*Microdus bipustulatus*)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 116 (1914) (*Disophrys tarsalis*)
BRUES, Ann. South African Mus., vol. 19, p. 86 (1924)
BRUES, Proc. American Acad. Arts & Sci., vol. 61, p. 284 (1925)

erythropus CAMERON TRANSVAAL
Ann. Trasvaal Mus., vol. 2, p. 205 (1911)

evanescens ENDERLEIN MADAGASCAR
Arch. Naturg., Jahrg 84A (1918), Heft 11, p. 188 (1920)

exilis ENDERLEIN MADAGASCAR
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 187 (1920)

flaviceps SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 213 (1914)

fraudator SZEPLIGETI CAMERUN, TOGO, TANGANYIKA TERR., COMORA ISL.
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 426 (1913)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 214 (1914)

guineënsis SZEPLIGETI GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 215 (1914)

insidiator SZÉPLIGETI SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 214 (1914)

intermedia SZÉPLIGETI BELGIAN CONGO
Rev. Zool. Africaine, vol. 3, p. 416 (1914)

iridipennis CAMERON MOZAMBIQUE
Rec. Albany Mus., Grahamstown, vol. 1, p. 158 (1905) (*Xanthomicrodus*)
BRUES, Ann. South African Mus., vol. 19, p. 86 (1924)

lutea BRULLÉ EQUATORIAL & SO. AFRICA & ADJACENT ISL., MADAGASCAR

Hist. Nat. Ins. Hymen., vol. 4, p. 506 (1846) (*Agathis*)
GERSTAECKER, Reise nach Mossam. p. 524 (1862) (*Agathis*)
SAUSSURE, in Grandidier, Hist. Madagascar, Hymén, pl. 15, fig. 27 (1890) (*Coccygidium*)
KRIECHBAUMER, Berliner Ent. Zeits., vol. 39, p. 312 (1894) (*Brachyrhopalum pallidum*)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 38 (1910)
SZÉPLIGETI, Wiss. Erbegn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 2, p. 414 (1911)
CAMERON, Ann. Soc. Ent. Belgique, vol. 56, p. 379 (1912) (*Xanthomicrodus pallidinervis*)
SZÉPLIGETI, Boll. Lab. Zool. Gen. Agrar., Portici, vol. 7, p. 103 (1913)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 426 (1913)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 188 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 416 (1914)
ENDERLEIN, Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 187 (1920)
BRUES, Ann. South African Mus., vol. 19, p. 86 (1924)
BRUES, Proc. American Acad. Arts & Sci., vol. 61, p. 284 (1926)

melanogaster SZÉPLIGETI BELGIAN CONGO

Ergebn. 2 ten. Zentral-Afrika Exped., vol. 1, p. 152 (1915)

mellea ROMAN KATANGA, NUBIA, KENYA COLONY

Ent. Tidskr., vol. 31, p. 121, fig. (1910)
SZÉPLIGETI, Mitt. Zool. Mus. Berlin, vol. 7, p. 214 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 416 (1914)

minor SZÉPLIGETI SPANISH GUINEA

Mitt. Zool. Mus., Berlin, vol. 7, p. 213 (1914)

mitra ENDERLEIN MADAGASCAR

Arch. Naturg., Jahrg. 84A (1918) Heft 11, p. 187 (1920)

natalensis SZÉPLIGETI BELGIAN CONGO, SOUTHERN AFRICA

Term. Füzetek, vol. 25, p. 71 (1902)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 416 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 117 (1914)
BRUES, Ann. South African Mus., vol. 19, p. 86 (1914)
BRUES, Proc. American Acad. Arts & Sci., vol. 61, p. 284 (1926)

nigricornis BRULLÉ SENEGAL, BELGIAN CONGO, TANGANYIKA TERR.

Hist. Nat. Ins. Hymén., vol. 4, p. 490 (1846) (*Agathis*)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 6, p. 413 (1908)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 417 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 117 (1914)

pallidinervis CAMERON

vide *lutea* Brullé

pedalis BRUES CAPE PROVINCE

Ann. South African Mus., vol. 19, p. 85 (1924)

picturata BRUES TRANSVAAL

Ann. South African Mus., vol. 19, p. 84 (1924)

punctata SZÉPLIGETI BELGIAN CONGO

Rev. Zool. Africaine, vol. 3, p. 417 (1914)

rufa CAMERON TRANSVAAL

Ann. South African Mus., vol. 5, p. 38 (1906)
BRUES, ibid., vol. 19, p. 86 (1924)

seminiger SZÉPLIGETI BELGIAN CONGO, NYASALAND

Wiss. Ergebn. deutsch. Zentral-Afrika Exped. vol. 3, p. 414 (1911)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 418 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 117 (1914)

severini SZÉPLIGETI BELGIAN CONGO

Rev. Zool. Africaine, vol. 3, p. 417 (1914)

striatus SZÉPLIGETI SPANISH GUINEA

Mitt. Zool. Mus., Berlin, vol. 7, p. 213 (1914)

tarsalis SZÉPLIGETI WESTERN EQUATORIAL AFRICA

Ann. Soc. Ent. Belgique, vol. 58, p. 116 (1914)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 215 (1914)

testacea CAMERON CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 38 (1906)

xanthostigma SZÉPLIGETI BELGIAN CONGO

Ergebn. 2 ten. Zent.-Afrika Exped., vol. 1, p. 153 (1915)

Agathis LATREILLE

Hist. Nat. Crust. Ins., vol. 13. p. 175 (1805)

areolaris SZÉPLIGETI ABYSSINIA

Mitt. Zool. Mus., Berlin, vol. 7, p. 217 (1914)

bovæi LUCAS ALGERIA

Explor. Sci. Algérie, Zool., vol. 3, p. 337 (1846)
BRULLÉ, Hist. Nat. Ins. Hymén., vol. 4, p. 486 (*erythromalus*)

brullei LUCAS ALGERIA

Explor. Sci. Algérie, Zool., vol. 3, p. 1846, p. 338 (1846)
MARSHALL, Spéc. Hymén. Europe, vol. 4, p. 569 (1890)

capensis CAMERON CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 37 (1906) (*Agathis*?)

foveola Brullé SENEGAL

Hist. Nat. Ins. Hymén., vol. 4, p. 491 (1846)

ornaticeps CAMERON BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 377 (1912)

ornaticornis CAMERON BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 377 (1912)

thoracica LUCAS ALGERIA

Explor. Sci. Algérie, Zool., vol. 3, p. 338 (1846)
MARSHALL, Hymén. Europe et Algérie, vol. 4, p. 569 (1890)

trifasciatus CAMERON BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 378 (1912)

Crassomicrodus ASHMEAD

Proc. U. S. Nat. Mus., vol. 23, p. 128 (1900)
BRADLEY, Psyche, vol. 23, p. 139 (1916)

Type: *C. fulvescens* Cresson

pumilus SZÉPLIGETI TRANSVAAL

Ent. Mitt., vol. 2, p. 385 (1913) (*Epimicrodus*)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 287 (1926)

Braunsia Kriechbaumer

Berliner Ent. Zeits., vol. 39, p. 62 (1894)

Type: *B. bilunata* Enderlein (*bicolor* Kriechbaumer)

analis KRIECHBAUMER TANGANYIKA TERRITORY

Berliner Ent. Zeits., vol. 39, p. 309 (1894)
ENDERLEIN, Zool. Jahrb. Abth. f. Syst., vol. 20, p. 443 (1904)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 219 (1914)

antennalis SZÉPLIGETI SIERRA LEONE

Ann. Mus. Nat. Hungarici, vol. 3, p. 52 (1905)

bilunata ENDERLEIN CAMERUN, SENEGAL, TANGANYIKA TERRITORY

Zool. Jahrb., Abth. f. Syst., vol. 20, p. 440 (1904)
KRIECHBAUMER, Berliner Ent. Zeits., vol. 39, p. 64 (1894) (*bicolor* nec Brullé 1846)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 38 (1910)

congoënsis ENDERLEIN SPANISH GUINEA, CONGO, BELGIAN CONGO

Zool. Jahrb. Abth. f. Syst., vol. 20, p. 437 (1904)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 418 (1914)
SZÉPLIGETI, Mitt. Zool. Mus. Berlin, vol. 7, p. 218 (1914)

enderleini SZÉPLIGETI KENYA COLONY, TANGANYIKA TERR.

Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 39 (1910)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 189 (1914)

erlangeri ENDERLEIN TANGANYIKA TERRITORY

Zool. Jahrb., Abth. f. Syst., vol. 20, p. 442 (1904)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 6, p. 420 (1908)

excelsa BRUES NATAL

Ann. South African Mus., vol. 19, p. 89 (1924)

fenestrata KRIECHBAUMER NATAL, SEYCHELLES, MADAGASCAR

Berliner Ent. Zeits., vol. 39, p. 310 (1894)
ENDERLEIN, Zool. Jahrb., Abth. f. Syst., vol. 20, p. 441 (1904)
CAMERON, Proc. Linn. Soc. London, Zool., (2) vol. 12, p. 83 (1907) (*melanoptera*)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 39 (1910)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 419 (1914)
SZÉPLIGETI, Mitt. Zool. Mus. Berlin, vol. 7, p. 219 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 117 (1914) (*melanoptera*)
ENDERLEIN, Arch. Naturg., Jahrg 84A (1918), Heft 11, p. 198 (1920)

fulvicollis CAMERON BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 379 (1912)

fuscipennis ENDERLEIN TOGO, SPANISH GUINEA, BELGIAN & FRENCH CONGO, CAMERUN

Zool. Jahrb. Abth. f. Syst., vol. 20, p. 436 (1904)
SZÉPLIGETI, Ark. Zool., vol. 2, No. 14, p. 11 (1905)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 218 (1914)

SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 117 (1914)
SZÉPLIGETI, Ergebn. 2 ten. Zent-Afrika Exped., vol. 1, p. 153 (1915)

kriegeri ENDERLEIN TANGANYIKA TERRITORY, MADAGASCAR
Zool. Jahrb., Abth. f. Syst., vol. 20, p. 444 (1904)
SZÉPLIGETI, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 426 (1913)

madagascariensis ENDERLEIN MADAGASCAR
Stettiner Ent. Zeitg., vol. 67, p. 257 (1906)

melanura ENDERLEIN CAPE PROVINCE
Zool. Jahrb., Abth. f. Syst., vol. 20, p. 446 (1904)

metanastriæ BRUES UGANDA
Proc. American Acad. Arts & Sci., vol. 61, p. 290 (1926)

mimetica BRUES NATAL
Ann. South African Mus., vol. 19, p. 88 (1924)

nigriceps CAMERON BELGIAN CONGO
Ann. Soc. Ent. Belgique, vol. 56, p. 378 (1912)

occidentalis ENDERLEIN EQUATORIAL AFRICA
Zool. Jahrb. Abth. f. Syst., vol. 20, p. 438 (1904)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 218 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 117 (1914)
ENDERLEIN, Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 198 (1920)

occidentalis, var. **obscurior** ENDERLEIN EQUATORIAL AFRICA
Zool. Jahrb., Abth. f. Syst., vol. 20, p. 439 (1904)
SZÉPLIGETI, Ann. Mus. Nat. Hungarici, vol. 6, p. 420 (1908)
SZÉPLIGETI, Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 39 (1910)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 218 (1914)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 418 (1914)
SZÉPLIGETI, Ann. Soc. Ent. Belgique, vol. 58, p. 117 (1914)
SZÉPLIGETI, Rés. Sci. Voyage Alluaud, p. 188 (1914)
SZÉPLIGETI, Ergebn. 2 ten. Zent.-Afrika Exped., vol. 1, p. 163 (1915)

ochracea ENDERLEIN CAPE PROVINCE
Zool. Jahrb., Abth. f. Syst., vol. 20, p. 445 (1904)

orientalis SZÉPLIGETI TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 218 (1914)

partita BRUES NATAL
Proc. American Acad. Arts & Sci., vol. 61, p. 289 (1926)

pleuralis Brues — Uganda
Proc. American Acad. Arts & Sci., vol. 61, p. 291 (1926)

pulchripennis Szépligeti — Belgian Congo
Ergebn. 2 ten Zent.-Afrika Exped., vol. 1, p. 153 (1915)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 419 (1914)

reicherti Enderlein — Togo, Spanish Guinea
Zool. Jahrb., Abth. f. Syst., vol. 20, p. 439 (1904)
Szépligeti, Mitt. Zool. Mus. Berlin, vol. 7, p. 219 (1914)

ruficeps Kriechbaumer — Guinea, Camerun
Berliner Ent. Zeits., vol. 39, p. 64 (1894)
Enderlein, Zool. Jahrb. Abth. f. Syst., vol. 20, p. 437 (1904)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 218 (1914)

similis Szépligeti — Camerun
Ark. Zool., vol. 2, No. 14, p. 11 (1905)

sjöstedti Szépligeti — Tanganyika Territory
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 39 (1910)
Szépligeti, Ann. Mus. Nat. Hungarici, vol. 6, p. 421 (1908)
Szépligeti, Wiss. Ergebn. deutsch Zentral-Afrika Exped. 1907–08, vol. 3, p. 414 (1911)

stellifera Szépligeti — Belgian Congo
Wiss. Ergebn. 2 ten. Zent.-Afrika Exped., vol. 1, p. 153 (1915)
Szépligeti, Rev. Zool. Africaine, vol. 3, p. 419 (1914)

trifasciata Enderlein — Madagascar
Arch. Naturg., Jahrg. 84A (1918), Heft 11, p. 198 (1920)

subsulcata Enderlein — Cape Province
Zool. Jahrb., Abth. f. Syst., vol. 22, p. 446 (1904)

tricolor Gerstaecker — Mozambique
Mon. Akad. Wiss. Berlin, p. 264 (1858) (*Agathis*)
Enderlein, Zool. Jahrb., Abth. f. Syst., vol. 23, p. 442 (1904)

Ærophilus Szépligeti

Termes. Füzetek, vol. 25, p. 73 (1902)
Type: *Æ. brullei* Szépligeti

dubiosus Szepligeti — Senegal
Mitt. Zool. Mus., Berlin, vol. 7, p. 217 (1914)

Bassus FABRICIUS

Syst. Piez., p. 93 (1804)
NEES, Nova. Act. Acad. Nat. Curios., vol. 9, p. 304 (1818) (*Microdus*) *Microdus* of later authors.

Type: *B. calculator* Fabricius

aciculatus BRUES — TANGANYIKA TERRITORY
Proc. American Acad. Arts. Sci., vol. 61, p. 285 (1926)

ambiguus KOHL — SOKÓTRA
Denkschr. Akad. Wiss. Berlin, vol. 71, p. 294 (1907) (*Microdus*)

antefurcalis SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 220 (1914) (*Microdus*)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 287 (1926)

concolor SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 219 (1914) (*Microdus*)

longiseta SZÉPLIGETI — CAMERUN
Mitt. Zool. Mus., Berlin, vol. 7, p. 219 (1914) (*Microdus*)

macronura SZÉPLIGETI — BELGIAN CONGO
Rev. Zool. Africaine, vol. 3, p. 419 (1914) (*Microdus*)

mesoxanthus SZÉPLIGETI — MADAGASCAR
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 426 (1913)

postfurcalis SZÉPLIGETI — SPANISH GUINEA
Mitt. Zool. Mus., Berlin, vol. 7, p. 220 (1914) (*Microdus*)

triangularis SZÉPLIGETI — TANGANYIKA TERRITORY
Mitt. Zool. Mus., Berlin, vol. 7, p. 219 (1914) (*Microdus*)

Spilomicrodus CAMERON

Timehri, Journ. Roy. Agric. Soc. Brit. Guiana, vol. 1, p. 323 (1911)
BRADLEY, Psyche, vol. 23, p. 140 (1916)

Type: *S. nigriceps* Cameron

curvinervis CAMERON — TRANSVAAL
Ann. Transvaal Mus., vol. 2, p. 205 (1911) (*Crassomicrodus*)

Hormagathis BRUES

Proc. American Acad. Arts Sci., vol. 61, p. 287 (1926)

Type: *H. mellea* Brues

mellea BRUES — NATAL
Proc. American Acad. Arts Sci., vol. 61, p. 288 (1926)

Subfamily MICROGASTRINÆ

Apanteles Förster

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 245 (1862)
Type: *A.* (*Microgaster*) *obscurus* Nees

africanus Viereck — Transvaal
Proc. U. S. Nat. Mus., vol. 40, p. 174 (April, 1911)

basimacula Cameron — Cape Province
Rec. Albany Mus., Grahamstown, vol. 1, p. 173 (1905)
Cameron, Ann. South African Mus., vol. 5, p. 204 (1906)

beneficus Viereck — Portuguese East Africa
Proc. U. S. Nat. Mus., vol. 40, p. 175 (1911)

cameroni Brues — Transvaal
Ann. South African Mus., vol. 19, p. 145 (1924)
Cameron, Ann. Transvaal Mus., vol. 2, p. 207 (1911) (*africanus*, nec Viereck, 1911)

capensis Cameron — Cape Province
Ann. South African Mus., vol. 5, p. 203 (1906)

carinatus Szépligeti — Tanganyika Territory
Ann. Mus. Nat. Hungarici, vol. 11, p. 602 (1913)

chrysippi Viereck — Portugese East Africa, Madagascar
Proc. U. S. Nat. Mus., vol. 40, p. 175 (1911)
Szépligeti, Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 426 (1913)

coxalis Szépligeti — Nyasaland
Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 413 (1911)

discretus Szépligeti — Kenya Colony
Rés. Sci. Voyage Alluaud, p. 185 (1914)

eurygaster Cameron — Transvaal
Ann. Transvaal Mus., vol. 2, p. 207 (1911)

falcatus Nees — Egypt (Europe)
Hymen. Ichneum. Affin. Monog., vol. 1, p. 175 (1834) (*Microgaster*)
Walker, List. Hymen. Egypt. p. 5 (1871) (*Microgaster*)
Marshall, Trans. Ent. Soc. London, 1885, p. 192 (1885)
Marshall, Spéc. Hymén. Europe, vol. 4, p. 442 (1889)

fuscinervis Cameron — Transvaal
Ann. Transvaal Mus., vol. 2, p. 207 (1911)

allicolus GIRAUD ALGERIA

Ann. Soc. Ent. France (4), vol. 9, p. 480 (1809) (*Microgaster*)
MARSHALL, Spéc. Hymén Europe, vol. 4, p. 493 (1890)

;lomeratus Linné NORTHERN AFRICA (Europe)

Syst. Nat. Ed. 10a, vol. 1, p. 568 (1758)
NEES, Hymen. Ichneum. affin. Monogr., vol. 1, p. 174 (1834)
MARSHALL, Trans. Ent. Soc. London, p. 176 (1885)
MARSHALL, Hymén. Europe et Algérie, vol. 4, p. 422 (1888)

gowdei GAHAN UGANDA

Proc. U. S. Nat. Mus., vol. 54, p. 589 (1918)

incompletus SZÉPLIGETI KILIMANDJARO, 10,000 FT.

Rés. Sci. Voyage Alluaud, p. 185 (1914)

lacteipennis SZÉPLIGETI TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 602 (1913)

langenburgensis SZÉPLIGETI NYASALAND

Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 412 (1911)

liopleuris SZÉPLIGETI TANGANYIKA TERRITORY

Rés. Sci. Voyage Alluaud, p. 185 (1914)

maculitarsis CAMERON CAPE PROVINCE

Rec. Albany Mus., vol. 1, p. 173 (1905)

orientalis SZÉPLIGETI TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 602 (1913)

pallidocinctus GAHAN UGANDA

Proc. U. S. Nat. Mus., vol. 54, p. 588 (1918)

rugosus SZÉPLIGETI KENYA COLONY

Rés. Sci. Voyage Alluaud, Hymen., p. 184 (1914)

testaceiventris CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 208 (1911) (*testaceioventris*)

testaceolineatus CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 208 (1918)

transvaalensis CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 208 (1911)

trochanteratus Szépligeti — Tanganyika Territory

Wiss. Ergebn. deutsch. Zentral-Afrika Exped. 1907–08, vol. 3, p. 412 (1911)

ugandaënsis Gahan — Uganda

Proc. U. S. Nat. Mus., vol. 54, p. 589 (1918)

Stenopleura Viereck

Proc. U. S. Nat. Mus., vol. 40, p. 187 (1911)

Type: *S. sesamiæ* Cameron

sesamiæ Cameron — Portugese E. Africa, Cape Province

Trans. South African Philos. Soc., vol. 16, p. 335 (1906) (*Apanteles*)
Viereck, Proc. U. S. Nat. Mus., vol. 40, p. 188 (1911)

Xestapanteles Cameron

Zeits. Naturwiss., vol. 81, p. 447 (1909)

Type: *X. latiannulatus* Cameron

latiannulatus Cameron — Mozambique

Zeits. Naturwiss., vol. 81, p. 448 (1909)

Microgaster Latreille

Hist. Nat. Crust. et Ins., vol. 3, p. 189 (1802)

Type: *M. deprimator* Fabr.

bicolor Szépligeti — Kenya Colony

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., 1907–08, vol. 3, p. 413 (1911)

carbonaria Holmgren — Mauritius

Eugenies Resa, vol. 2, p. 433 (1868)

fasciipennis Gahan — Uganda

Proc. U. S. Nat. Mus., vol. 54, p. 587 (1918)

Microplitis Förster

Verh. naturf. ver. preuss. Rheinlande, vol. 19, p. 245 (1862)

Type: *M. sordipes* Nees

tunetensis Marshall — Tunis

Bull. Mus. Hist. Nat. Paris, vol. 6, p. 363 (1900)

Urogaster ASHMEAD

Trans. Ent. Soc. London, p. 286 (1900)
ASHMEAD, Proc. U. S. Nat. Mus., vol. 23, p. 132 (1900)

Type: *U. vulgaris* Ashmead.

arbonaria Holmgren MAURITIUS

Eugenies Resa, Ins., p. 433 (1868) (*Microgaster*)
ROMAN, Ent. Tidskr., vol. 31, p. 140 (1910)

uscicornis CAMERON CAPE PROVINCE

Zeits, Naturw., vol. 81, p. 449 (1909)

Mirax HALIDAY

Entom. Mag., vol. 1, p. 263 (1833)

Type: *M. rufilabris*

africana BRUES NATAL

Proc. American Acad. Arts Sci., vol. 61, p. 292 (1926)

SUBFAMILY METEORINÆ

Meteorus HALIDAY

Entom. Mag., vol. 3, p. 24 (1835)

Type: *M. pendulator* Latreille

atrator CURTIS ALGERIA (Europe)

British Entom., vol. 9, p. 415 (1832) (*Zele*)
NEES, Hymen. Ichneum. affin. Monog., vol. 1, p. 41 (1834) (*Perilitus similator*)
MARSHALL, Spéc. Hymén. Europe, vol. 5, p. 96 (1891)

durbanensis BRUES NATAL

Proc. Amer. Acad. Arts & Sci., vol. 61, p. 294 (1926)

fasciatus BRUES NATAL

Proc. Amer. Acad. Arts & Sci., vol. 61, p. 295 (1926)

flavicornis SZÉPLIGETI TANGANYIKA TERRITORY

Mitt. Zool. Mus. Berlin, vol. 7, p. 228 (1914)

kleini SZÉPLIGETI BRIT. SOUTHWEST AFRICA

Beitr. Landf. Südwestafrikas, vol. 1, p. 191 (1918)

laphygmarum BRUES RHODESIA

Proc. American Acad. Arts & Sci., vol. 61, p. 296 (1926)

neavei Brues — Nyasaland
Proc. American Acad. Arts & Sci., vol. 61, p. 297 (1926)
testaceus Szépligeti — Tanganyika Territory
Mitt. Zool. Mus. Berlin, vol. 7, p. 228 (1914)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 295 (1926)
tricolor Szépligeti — Tanganyika Territory
Ann. Mus. Nat. Hungarici, vol. 11, p. 607 (1913)
trilineatus Cameron — Cape Province
Rec. Albany Mus., Grahamstown, vol. 1, p. 242 (1906)
Brues, Proc. Amer. Acad. Arts Sci., vol. 61, p. 298 (1926)

Subfamily EUPHORINÆ

Euphorus Nees

Hymen. Ichneum. Affin. Monog., vol. 2, p. 360 (1834)
Type: *E. pallicornis*

nigricarpus Szépligeti — Tanganyika Territory
Ann. Mus. Nat. Hungarici, vol. 11, p. 607 (1913)
petiolatus Wollaston — Madeira
Ann. Mag. Nat. Hist. (3), vol. 1, p. 23 (1858)
xanthostigma Szépligeti — Kenya Colony
Rés. Sci. Voyage Alluaud, p. 197 (1914)

Perilitus Nees

Nov. Act. Acad. Nat. Curios, vol. 9, p. 302 (1818)
Type: *P. rutilus* Nees

angustatus Brues — Cape Province
Ann. South African Mus., vol. 19, p. 104 (1924)
brevicollis Haliday — Algeria (Europe)
Entom. Mag., vol. 3, p. 35 (1835)
Marshall, Trans. Ent. Soc. London, 1887, p. 76 (1887)
Marshall, Spéc. Hymén. Europe, vol. 5, p. 40 (1891)
debilis Wollaston — Madeira
Ann. Mag. Nat. Hist. (3) vol. 1, p. 23 (1858)
latus Brues — Cape Province
Ann. South African Mus., vol. 19, p. 104 (1924)

mophli LESNE ALGERIA

Ann. Soc. Ent. France, vol. 61, p. 305 (1892)
MARSHALL, Hymén. Europe et Algérie, vol. 5 bis, p. 215 (1898)

uficollis CAMERON CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 29 (1906)

Streblocera WESTWOOD

Philos. Mag. (3), vol. 3, p. 342 (1833)
Type: *S. fulviceps* Westwood

insperata TURNER CAPE PROVINCE

Ann. Mag. Nat. Hist. (9), vol. 10, p. 280 (1922)

Dinocampus FÖRSTER

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 252 (1862)
Type: *D. terminatur* Nees

fulvogaster BRUES NATAL

Proc. Amer. Acad. Arts & Sci., vol. 61, p. 299 (1926)

luteus SZÉPLIGETI KILIMANDJARO 12,000 FT.

Mitt. Zool. Mus. Berlin, vol. 7, p. 228 (1914)

nigrogaster BRUES NATAL

Proc. Amer. Acad. Arts & Sci., vol. 61, p. 300 (1926)

SUBFAMILY HELORIMORPHINÆ

Helorimorpha SCHMIEDEKNECHT

Hymen. Mitteleuropas, p. 523 (1907)
CAMERON, Soc. Ent. Jahrg. 24, p. 9, (1909) (*Stictometeorus*)
Type: *H. egregia* Schmiedeknecht

africana BRUES ZULULAND, NATAL

Ann. South African Mus., vol. 19, p. 101 (1924)
BRUES, Proc. American Acad. Arts Sci., vol. 61, p. 301 (1926)

bicolor SZÉPLIGETI TANGANYIKA TERRITORY

Ann. Mus. Nat. Hungarici, vol. 11, p. 608 (1913) (*Stictometeorus*)

cameroni SZÉPLIGETI TANGANYIKA TERRITORY

Mitt. Zool. Mus., Berlin, vol. 7, p. 229 (1914) (*Stictometeorus*)

coffeæ Brues — Tanganyika Territory, Natal

Ann. South African Mus., vol. 19, p. 103 (1924)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 301 (1926)

lutea Szépligeti — Tanganyika Territory, Natal

Ann. Mus. Nat. Hungarici, vol. 11, p. 608 (1913) (*Stictometeorus*)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 301 (1926)

rufa Cameron — Natal, Cape Province

Soc. Entom., Jahrg., p. 9 (1909) (*Stictometeorus*)
Brues, Proc. American Acad. Arts Sci., vol. 61, p. 301 (1926)

FAMILY ALYSIIDÆ

Subfamily DANCUSINÆ

Cœlinius Nees.

Nov. Act. Acad. Nat. Curios., vol. 9, p. 301 (1818)
Curtis, British Ent., vol. 6, p. 289 (1829)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 230 (1914) (*Chænon*)

Type: *C. parvulus* Nees

ater Szépligeti — Kilimandjaro, 9,000–12,000 Ft.

Mitt. Zool. Mus., Berlin, vol. 7, p. 230 (1914) (*Chænon*)

Heratemis Walker

Ann. Mag. Nat. Hist. (3), vol. 5, p. 310 (1860)

Type: *H. filosa* Walker

longicornis Brues — Zululand

Ann. South African Mus., vol. 19, p. 112 (1924)

Subfamily ALYSIINÆ

Aphæreta Förster

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 264 (1862)

Type: *A. minuta* Nees

sarcophagæ Bridwell — Cape Province

Holcalysia Cameron

Entomologist, vol. 38, p. 268 (1905)

Type: *H. testaceipes* Cameron

testaceipes Cameron — Cape Province

Entomologist, vol. 38, p. 269 (1905)

Cœlalysia CAMERON

Ann. Transvaal Mus., vol. 2, p. 212 (1911)
TURNER, Bull. Ent. Research, vol. 177 (1917)

Type: *C. lutea* Cameron

bicolor SZÉPLIGETI NYASALAND, TANGANYIKA TERRITORY

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 417 (1911) (*Idiasta*)
SZEPLIGETI, Rés. Sci. Voyage Alluaud, p. 196 (1914) (*Idiasta*)
TURNER, Bull. Ent. Research, vol. 8, p. 177 (1917)

camerunensis ENDERLEIN

Arch. Naturg., Jahrg. 78A Heft 6, p. 100 (1912) (*Alysia*)
TURNER, Bull. Ent. Research, vol. 8, p. 177 (1917)

glossinophaga TURNER GOLD COAST

Bull. Ent. Research, vol. 8, p. 177 (1917)

goniarcha CAMERON BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 381 (1912) (*Alysia*)
TURNER, Bull. Ent. Research, vol. 8, p. 177 (1917)

lusoriæ BRIDWELL CAPE PROVINCE

Proc. Hawaiian Ent. Soc., vol. 4, p. 175 (1919) (*Alysia*)
BRUES, Ann. South African Mus., vol. 19, p. 111 (1924)

lutea CAMERON TRANSVAAL

Ann. Transvaal Mus., vol. 2, p. 212 (1911)
TURNER, Bull. Ent. Research, vol. 8, p. 177 (1917)

maculiceps CAMERON BELGIAN CONGO

Ann. Soc. Ent. Belgique, vol. 56, p. 381 (1912) (*Alysia*)
TURNER, Bull. Ent. Research, vol. 8, p. 177 (1917)

nigriceps SZÉPLIGETI EQUATORIAL AFRICA

Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 417 (1911) (*Idiasta*)
SZÉPLIGETI, Mitt. Zool. Mus., Berlin, vol. 7, p. 229 (1914) (*Idiasta*)
SZÉPLIGETI, Rev. Zool. Africaine, vol. 3, p. 420 (1914)
TURNER, Bull. Ent. Research, vol. 8, p. 177 (1917)

Alitha CAMERON

Ann. South African Mus., vol. 5, p. 28 (1906)

Type: *A. longipennis* Cameron

longipennis CAMERON CAPE PROVINCE

Ann. South African Mus., vol. 5, p. 28 (1906)

Idiasta Förster

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 265 (1862)
Type: *I. maritima* Haliday

africana Szépligeti — Spanish Guinea, Camerun, Tanganyika Terr.
Mitt. Zool. Mus., Berlin, vol. 7, p. 229 (1914)

postscutellaris Szépligeti — Tanganyika Territory
Wiss. Ergebn. Kilimandjaro-Meru Exped., vol. 2, p. 42 (1910)

Phænocarpa Förster

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 267 (1862)
Kriechbaumer, Berliner Ent. Zeits., vol. 39, p. 66 (1894) (*Dapsilarthra*)
Type: *P. picinervis* Haliday

cristata Szépligeti — Camerun, Belgian Congo
Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 154 (1915)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 229 (1914)

madagascariensis Szépligeti — Madagascar
Wiss. Ergebn. Reise Voeltzkow, vol. 3, p. 428 (1913)

nigriceps Kriechbaumer — Belgian Congo
Berliner Ent. Zeits, vol. 39, p. 66 (1894) (*Dapsilarthra*)
Szépligeti, Ergebn. 2ten. Zent.-Afrika Exped., vol. 1, p. 154 (1915)

pulchricornis Szépligeti — Camerun, Taganyika Territory
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 417 (1911)
Szépligeti, Mitt. Zool. Mus., Berlin, vol. 7, p. 229 (1914)

? testaceipes Cameron — Cape Province
Zeits. Hymen. Hipt., 1905, p. 343 (1905)

Tolbia Cameron

Trans. Linn. Soc. London, (2), vol. 12, p. 84 (1907)
Type: *P. scævolæ* Cameron

scævolæ Cameron — Isle de la Passe
Trans. Linn Soc. London (2), vol. 12, p. 85 (1907)

Aspilota Förster

Verh. naturh. Ver. preuss. Rheinlande, vol. 19, p. 268 (1862)
Type: *A.* (*Alysia*) *ruficornis* Nees

incompleta SZÉPLIGETI TANGANYIKA TERRITORY
Wiss. Ergebn. deutsch. Zentral-Afrika Exped., vol. 3, p. 418 (1911)

Libyophilus KIEFFER

Ann. Soc. Sci., Bruxelles, vol. 30, p. 115 (1906)
Type: *L. villosus* Kieffer

villosus KIEFFER ALGERIA
Ann. Soc. Sci., Bruxelles, vol. 30, p. 115 (1906)

INCERTÆ SEDIS

Allochromus MARSHALL

Agric. prat. pays chauds, p. 643 (1902)
Type: *A. trimerocleri* Marshall.

trimerocleri MARSHALL MADAGASCAR
Agric. prat. pays chauds, p. 643 (1902)

Bracon, *sens. latiss.*

æquitator WIEDEMANN CAPE PROVINCE
Analect. Ent., p. 8 (1824)

difficilis CAMERON CAPE PROVINCE
Ann. South African Mus., vol. 5, p. 58 (1906) (*Bracon* ?)
This may be a Glyptomorpha.

erythrothorax LUCAS ALGERIA
Explor. Sci. Algérie, Zool., vol. 3, p. 335 (1846)
Marshall, Spéc. Hymén. Europe et Algérie, vol. 4, p. 170 (1888)

itinerator FABRICIUS GUINEA
Ent. Syst., vol. 2, p. 175 (1793) (*Ichneumon*)
FABRICIUS, Syst. Piez., p. 102 (1804)
THUNBERG, Mem. Acad. St. Petersbourg, vol. 8, p. 260 (1822) (*Ichneumon*)
THUNBERG, ibid., vol. 9, p. 309 (1824) (*Ichneumon*)

Lorenzoa DE STEFANI PÉREZ

Marcellia, vol. 8, p. 15 (1909)
Type: *L. solani* Pérez

solani DE STEFANI PÉREZ ERITREA
Marcellia, vol. 8, p. 16 (1909)

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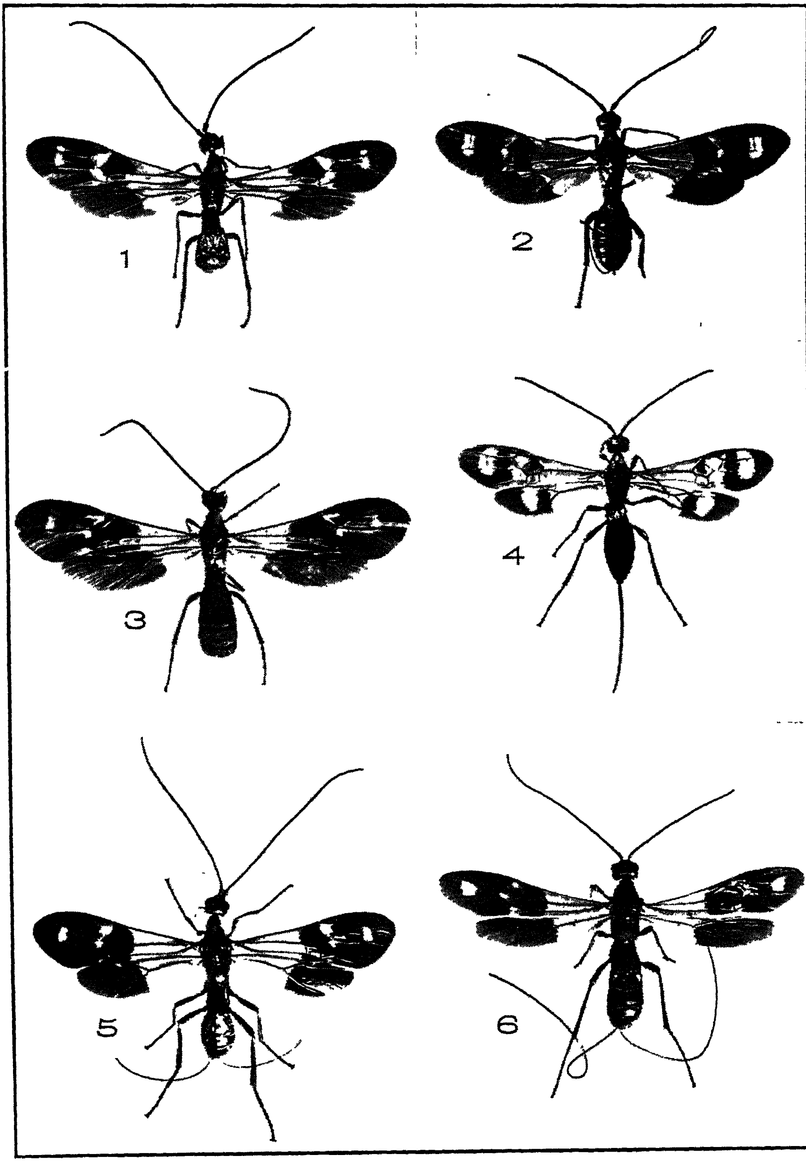
EXPLANATION OF PLATES.

PLATE I.

Figure 1. *Iphiaulax phosphor* Brues.
Figure 2. *Iphiaulax martinii* Gribodo.
Figure 3. *Mesobracon capensis* Szépligeti.
Figure 4. *Archibracon pulchripennis* Cameron.
Figure 5. *Archibracon servillei* Brullé.
Figure 6. *Odontobracon spilopterus* Cameron.

PLATE II.

Figure 7. *Ogmophasmus erythrothorax* Cameron.
Figure 8. *Braunsia mimetica* Brues.
Figure 9. *Hyrtanommatium terebrator* Brues.
Figure 10. *Braunsia pleuralis* Brues.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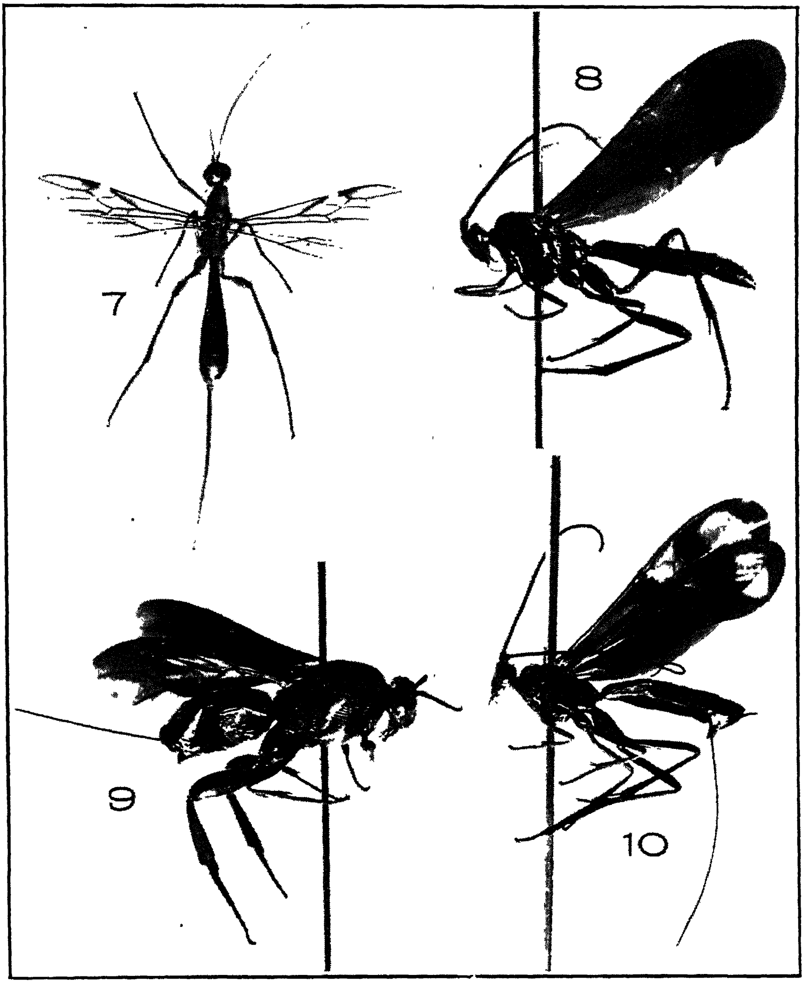
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Proceedings of the American Academy of Arts and Sciences.

Vol. 61. No. 9.—July, 1926.

STUDIES IN THE UREA SERIES. TRANSFORMATIONS OF NITROGUANIDINE.

By Tenney L. Davis and Armand J. J. Abrams.

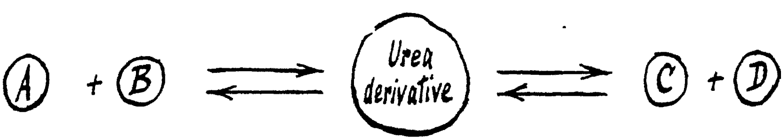
Contribution No. 5 from the Massachusetts Institute of Technology, Research Laboratory of Organic Chemistry.

STUDIES IN THE UREA SERIES. TRANSFORMATIONS OF NITROGUANIDINE.

By Tenney L. Davis and Armand J. J. Abrams.

Urea, thiourea, guanidine, and many of their derivatives, when heated, break down—often in more than one manner—to yield precisely those smaller molecules by the direct combination of which the urea derivatives may be synthesized.[1] Since the breaking down is orderly and predictable, it has been called the *urea dearrangement,* that name being chosen in preference to "disarrangement" which connotes a disorderly breaking down and in preference to "dissociation" or "disassociation" which names now commonly apply to the breaking apart of more or less polarized atoms or molecules. The urea dearrangement may be defined as the breaking down of a urea derivative in such manner that the hydrogen atom, previously attached to one of the nitrogen atoms, goes off in combination with the other nitrogen atom and the atoms or groups originally attached to it, deserting the rest of the molecule. It gives rise to ammonia or a substituted ammonia and to cyanic acid or a substituted cyanic acid. If each nitrogen atom of an unsymmetrical urea derivative carries an hydrogen atom, two modes of dearrangement are possible and occur simultaneously.

Many reactions then in the urea series consist in the direct combination or un-combination of electrically neutral molecules, without metathesis, in a predictable manner, thus—

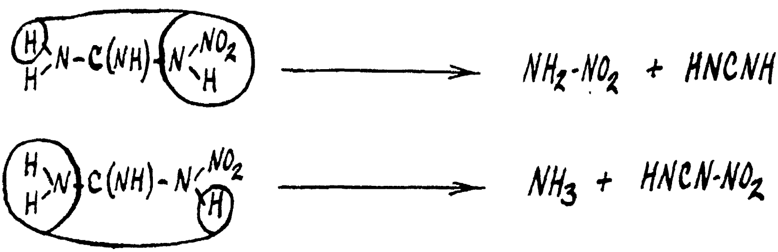


Referring to the diagram above, it may frequently happen that the substances, *A* and *B*, and consequently the urea derivative itself, are easily prepared and readily accessible. The substance, *C* or *D*, may be one which is much desired as a material for synthesis, but which

[1] *Jour. Amer. Chem. Soc.* *44*, 2595 (1922); *45*, 1816 (1923): *Proc. Nat. Acad. Sciences.* *11*, 68 (1925).

cannot be obtained easily or is very expensive or difficult to handle. If, however, the urea derivative is heated with a substance with which *C* is capable of reacting, it dearranges reversibly to form *A*, *B*, *C*, and *D*; *C* is removed from the equilibrium, *A* and *B* recombine to form the urea derivative which produces more of *C*, and the urea derivative for the purpose of the synthesis acts as a convenient source of its dearrangement product. By working on this principle we have prepared from nitroguanidine certain substituted guanidines on the one hand, and substances of a new type, the alkyl nitroguanidines, on the other.

Nitroguanidine differs from urea in having a nitro group in place of an hydrogen atom and an imino group in place of the oxygen. It would be expected to dearrange in two modes, as follows—



The reactions of nitroguanidine when dissolved in conc. sulfuric acid suggest that dearrangement occurs in this solvent. Its reactions in water solution support the belief that in aqueous solution it dearranges in both modes. When it is decomposed by heat, cyanamide and ammonia are produced as such, and the other products are precisely those which would result from the decomposition, polymerization, and interaction of the expected dearrangement products.

The experiments which are described in the present paper, unless otherwise stated, were carried out with the more common and more stable *alpha* form of nitroguanidine.[2] Among the products of its decomposition by heat we have found a certain quantity of the unstable *beta*-nitroguanidine.

Nitroguanidine is a powerful explosive, remarkable for the fact that it is exceptionally cool. It has been used in mixture with colloided nitrocellulose for the manufacture of flashless propellant powders. These powders have the same ballistic power, weight for weight, as

[2] *Jour. Amer. Chem. Soc.* *47*, 1063 (1925).

powders made entirely from nitrocellulose, but have the disadvantages that they produce a thin gray smoke and yield gases which contain ammonia. The presence of these products is readily explained by an understanding of the decomposition of nitroguanidine by heat.

Reactions of Nitroguanidine in Conc. Sulfuric Acid Solution.

Nitroguanidine dissolves readily in cold conc. sulfuric acid and precipitates out again if the liquid is diluted with water. If its solution in this reagent is heated, nitrous oxide comes off, and ammonia and carbon dioxide are produced quantitatively in accordance with the equation,

$$NH_2\text{-}C(NH)\text{-}NH\text{-}NO_2 + HOH \rightarrow N_2O + 2NH_3 + CO_2,$$

but a long continued heating at an elevated temperature is necessary to complete the decomposition.[3] Indeed, the nitrous oxide comes off first and fairly rapidly, while the carbon dioxide comes off later and more slowly, a fact which suggests that the solution contains not one substance, the nitroguanidine, but two or more substances, the dearrangement products, one of which is attacked by warm sulfuric acid more readily to yield nitrous oxide, the other less readily to yield carbon dioxide. Moreover, the production of nitrous oxide is not quantitative: the gases contain elementary nitrogen as would be expected if nitroamide were present in the solution.[4]

Although a solution of nitroguanidine in conc. sulfuric acid appears to contain little or no nitric acid (for it yields nitrous oxide when heated), it nevertheless contains some substance which is capable of ready conversion into nitric acid, for it gives up its nitro group quantitatively in the nitrometer[5] and the solution has been found to be a satisfactory reagent for the nitration of such substances as aniline, phenol, and acet-*p*-toluide, which are soluble in conc. sulfuric acid. It seems unlikely that the nitric acid effective in these reactions is produced from guanidine nitrate resulting from the hydration of nitroguanidine, for in that case the nitric acid would be free in the strongly acid solution and would distil out when it is heated. If it is produced in the solution by the hydration of nitroamide or of nitrocyanamide from the dearrangement, then cyanamide would be left in the solution after the nitric is removed. We have found that cy-

[3] *Jour. Amer. Chem. Soc. 44*, 868 (1922).

[4] *Jour. Amer. Chem. Soc. 47*, 1043 (1925).

[5] Cope and Barab, *Jour. Amer. Chem. Soc. 38*, 2552 (1916).

anamide in ammoniacal solution reacts slowly with ammonium picrate in the cold to produce guanidine picrate, and believe that we have found evidence of cyanamide in a sulfuric acid solution of nitroguanidine by treating the solution with an excess of aniline for the removal of nitric acid, diluting, making ammoniacal, adding ammonium picrate, and obtaining guanidine picrate.

Reactions of Nitroguanidine in Aqueous Solution.

If nitroguanidine in aqueous solution dearranges reversibly to form on the one hand nitroamide and cyanamide, on the other ammonia and nitrocyanamide, the effect of adding ammonia to the liquid would be to disturb the equilibrium and to restore a part of the nitroguanidine which had broken down into ammonia and nitrocyanamide. The excess ammonia would also react with the cyanamide to produce guanidine. If the solution were warmed, the nitroamide would break down into water and nitrous oxide, the nitrocyanamide, by analogy with the known reaction of other nitroamines, would probably break down into nitrous oxide and cyanic acid, and the cyanic acid would combine with ammonia to form urea. All of these things appear to happen, for nitroguanidine on treatment with ammonia water yields guanidine and urea. The guanidine takes up carbon dioxide from the air and is obtained as carbonate.

Guanidine carbonate may be obtained in a yield equal to about 40% of the theoretical amount by evaporating a solution of nitroguanidine in a large excess of strong ammonia water slowly on the steam bath, and results practically pure if the dry residue is washed with alcohol for the removal of urea. The same material is produced in a yield of about 90% when nitroguanidine is digested at 65° with an excess of ammonium carbonate in aqueous solution. Nitrous oxide comes off, and after 10 or 12 hours the nitroguanidine has disappeared entirely. The residue from the evaporation of the liquid consists of guanidine carbonate along with small amounts of urea and of melamine. The last-named substance supplies further probable evidence that cyanamide was present in the solution. The guanidine carbonate is entirely free from nitrate, and this method appears to be preferable, for the preparation of pure material, to the more usual double decomposition methods which involve repeated crystallizations.

When nitroguanidine is repeatedly recrystallized from the same water or refluxed for some time in water solution, the liquid becomes distinctly ammoniacal. The dearrangement products evidently react among themselves to produce guanidine, for ammonium picrate,

added to a solution which had been refluxed for 60 hours, yielded guanidine picrate equal to 1.6% of the total amount of possible guanidine.

When nitroguanidine is heated with aqueous methylamine solution in a sealed tube at 100°, or boiled under reflux with the same reagent, a small amount of methylguanidine is produced. Refluxed with aniline in water solution it yields a very small amount of phenylguanidine along with phenylurea and a considerable amount of *sym*-diphenylurea. The substituted guanidines are evidently produced from cyanamide, the phenylurea from cyanic acid resulting from the decomposition of nitrocyanamide, and the diphenylurea as would be expected from the phenylurea in boiling aqueous solution.

More interesting results are obtained by working with aqueous solutions at temperatures (60°–70°) at which the nitrocyanamide would be expected not to decompose and accordingly to react with the amines to produce substituted nitroguanidines, thus—

$$HNCN\text{-}NO_2 + R\text{-}NH_2 \rightarrow R\text{-}NH\text{-}C(NH)\text{-}NH\text{-}NO_2.$$

When a suspension of nitroguanidine in water containing a molecular equivalent of methylamine is warmed to 60° or 70°, the nitroguanidine disappears rapidly, ammonia comes off in abundance, and the reaction is complete within a few minutes. The methylnitroguanidine is separated from unchanged nitroguanidine by solution in alcohol from which solvent it may be recrystallized. The residues contain methylguanidine. *Alpha-* and *beta*-nitroguanidine yield the same product.

Methylnitroguanidine dissolves readily in cold conc. sulfuric acid. If the solution is warmed, nitrous oxide comes off first, then a gas which extinguishes a glowing splint, and the remaining liquid, if diluted, made alkaline, and distilled, yields methylamine. The reaction indicates the structure which would be expected from the method of synthesis, namely, that in which the nitro group and the methyl group are attached to different nitrogen atoms, and is evidently as follows—

$$CH_3\text{-}NH\text{-}C(NH)\text{-}NH\text{-}NO_2 + HOH \rightarrow$$
$$CH_3\text{-}NH_2 + NH_3 + N_2O + CO_2.$$

If the nitro group and the methyl group were attached to the same nitrogen atom, methylamine would probably not be produced, for methylnitramine is decomposed by strong sulfuric acid to produce

nitrous oxide which escapes and methyl alcohol which reacts further with the acid.[6]

We have prepared other substituted nitroguanidines from ethyl, *n*-butyl, and benzyl amines, but have been unable to prepare phenylnitroguanidine from aniline by the same reaction. In the preparation of benzylnitroguanidine, benzylurea was found in the reaction mixture, a fact which suggests that the nitrocyanamide in part combines with the benzylamine and in part breaks down to form cyanic acid which then combines with the base. The alkyl-nitroguanidines are soluble in water, in alcohol, and in conc. sulfuric acid, and give up their nitro group quantitatively in the nitrometer. They are being studied further in this laboratory. Benzylnitroguanidine is soluble in alcohol, but less soluble in water than nitroguanidine itself. It chars when treated with conc. sulfuric acid.

Decomposition of Nitroguanidine by Heat.

If a small quantity of nitroguanidine is warmed in a test tube, it melts at about 232° to a colorless liquid which effervesces, turns yellow and effervesces more violently, giving off water, and ammonia, and other material which collects as a white sublimate in the upper part of the tube, and leaves a buff colored residue which becomes bright yellow on stronger heating. If the tube, after cooling, is rinsed out with water, the wash waters show the presence of cyanamide when tested with copper sulfate or with ammoniacal silver nitrate. In some experiments the wash waters showed the presence of cyanic acid by Werner's test,[7] in others they failed to do so. Working with a large amount of material, we have found many substances in the sublimate and residue, the relation of which to the expected dearrangement products is shown in the diagram on next page.

When the gases from the decomposition were passed through water and through potassium hydroxide solution, the water was found to contain carbon dioxide, evidently from the interaction of cyanic acid and water vapor at the elevated temperature, and the alkaline solution was found to contain prussic acid and cyanic acid, substances which may very well have been produced as such by the decomposition or which may equally have been produced by the interaction of cyanogen, from the decomposition, with the alkali in the solution. The presence

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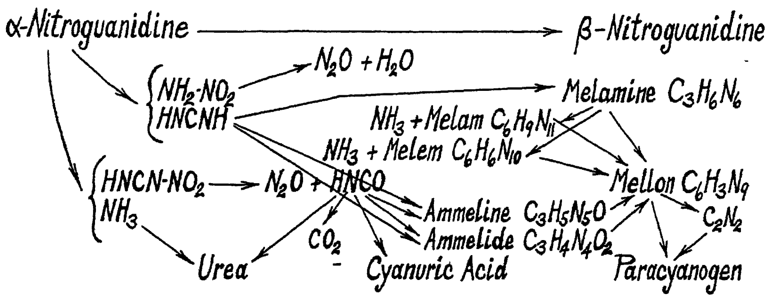
[6] Franchimont and Umbgrove, *Rec. trav. chim.* *17*, 287 (1898); Kranzler, *Bachelor's Thesis*, Mass. Inst. Tech. 1925.

[7] Werner, *Jour. Chem. Soc.* *123*, 2577 (1923).

of cyanic acid in the products of decomposition was further substantiatiated by the isolation from the solid residue of its trimer, cyanuric acid, and from the sublimate of urea, formed evidently by the combination of cyanic acid and ammonia in the gas phase. Cyanamide was found in the sublimate, and its trimer, melamine, in the sublimate and in the residue. Melam and melem, formed from melamine by the loss, from two molecules, of one molecule and of two molecules respectively of ammonia, were also found in the residue



along with ammeline and ammelide, reaction products of cyanic acid with cyanamide. Mellon, a yellow material which is produced by the heating of any of these last named substances, was also found in the residue. When mellon is heated further, it breaks down into nitrogen, prussic acid, and cyanogen. Cyanogen polymerizes to paracyanogen. Paracyanogen was isolated from the residue and identified.

The residue from the decomposition weighed about 25% as much as the original nitroguanidine and contained slightly more than 20% of its own weight of the unstable β-form.

Reactions of Nitrosoguanidine in Aqueous Solution.

Nitrosoguanidine explodes when heated or when treated with strong sulfuric acid. When warmed in aqueous solution, it breaks down, as Pellizzari has shown,[8] into cyanamide, water, and nitrogen—a reaction which appears to be plausibly explained by supposing that it dearranges into cyanamide and nitrosoamide and that the nitrosoamide on warming breaks down into nitrogen and water.

$$NH_2\text{-}C(NH)\text{-}NH\text{-}NO \rightarrow HNCNH + NH_2\text{-}NO \rightarrow N_2 + H_2O.$$

The hypothesis that the nitrogen comes from guanidine nitrite pro-

[8] Pellizzari, *Atti. accad. Lincei. 31* [I], 171 (1921).

duced by the hydration of nitrosoguanidine, or from ammonium nitrite produced by the dearrangement of guanidine nitrite, is not tenable, for we have found that guanidine nitrite gives off no gas when boiled in aqueous solution.

The probable presence of nitrosoamide in an aqueous solution of nitrosoguanidine is further indicated by the fact that the solution yields nitrous acid under the hydrating action of hydrochloric acid. Nitrosoguanidine dissolves in cold conc. hydrochloric acid to form a yellow solution which gives off red oxides of nitrogen when it is warmed. Added to a cold acidified solution of dimethylaniline or of diphenylamine, nitrosoguanidine converts these substances into their nitroso derivatives.

Experiments.

Decomposition of Nitroguanidine by Hot Conc. Sulfuric Acid.

The reaction was studied by heating a solution of 380 milligrams of nitroguanidine in 30 c.c. of conc. sulfuric acid in a 50 c.c. side-arm flask in an oil bath with a thermometer in the oil. The temperature was raised just rapidly enough to maintain an evolution of gas. The gas was collected over mercury in several portions which were analysed separately in order that it might be known which gases came off in greatest amount at the beginning. In an experiment in which the apparatus was filled with air at the start, gas evolution commenced at about 130° and five portions were collected below 223°, a total of 189.5 c.c. of gas, of which 28.0 c.c. was carbon dioxide, 74.5 c.c. nitrous oxide, 8.0 c.c. oxygen, and 78.1 c.c. nitrogen. Since 8.0 c.c. of oxygen is associated in the air with about 32 c.c. of nitrogen, it was apparent that considerable nitrogen had been produced from the nitroguanidine. Experiments were accordingly carried out in which the apparatus was filled with oxygen at the start and swept out with oxygen at the end. The results of a typical experiment, tabulated below, show that nitrous oxide comes off more rapidly than carbon dioxide and that considerable nitrogen is also produced.

	Temperature Interval	Volume of Sample (c.c.)	Composition of Sample (c.c.)			
			CO_2	O_2	N_2O	N_2
First Sample	135°–170°	50.0	3.5	17 5	16.0	13.0
Second "	170°–220°	48.0	13.0	2.0	28.0	5.0
Third "	220°–270°	49.0	22.0	2.0	20.5	4.5
Fourth "	270°–315°	29.0	14.0	1.5	9.5	4.0
Fifth "	315°–330°	55.5	26.5	21.5	3.0	4.5
Total	135°–330°	231.5	79.0	44 5	77.0	31.0

Nitrations with Nitroguanidine.

Nine and four-tenths grams of aniline was dissolved in 25 c.c. of conc. sulfuric acid, the mixture being warmed until solution was complete, and finally cooled in ice. Ten and four-tenths grams of nitroguanidine was dissolved in 50 c.c. of conc. sulfuric acid at a temperature below 2°, and the solution was added, slowly and with stirring, to the aniline solution while the temperature was kept below 2°. After standing 24 hours, first in ice-water and later at room temperature, the mixture was poured into ice-water, made ammoniacal, and the precipitate was steam-distilled in vacuum. The distillate by extraction with ether yielded 1.9 grams (13.8%) of a mixture of *o*- and *m*-nitroaniline, solidification point 90°, and the residue, recrystallized from water, yielded 2.76 grams (19.7%) of *p*-nitroaniline, m.p. 147°.

In a similar experiment the temperature was kept below —4° during the mixing, and the crude nitro compounds were extracted with chloroform from the ammoniacal ice-water in which the mixture had been drowned. The chloroform deposited 13.4 grams of material 96% of the theoretical amount. Examined by the method described by Holleman and his co-workers,[9] this was found to consist of 6.5% *p*-nitroaniline, 46.7% *m*-nitroaniline, and 46.8% *o*-nitroaniline.

Phenol was nitrated by adding nitroguanidine to a solution of the substance in conc. sulfuric acid. After standing at room temperature, the mixture was heated for 10 minutes in the boiling water bath, diluted, and distilled with steam. The first portions of the distillate yielded about 20% of the theoretical amount of *o*-nitrophenol, and the later portions a small amount of 2, 4-dinitrophenol.

Three grams of acet-*p*-toluide was dissolved in 10 c.c. of conc. sulfuric acid and nitrated by the addition of 2.1 grams of nitroguanidine. After everything had gone into solution, the mixture was heated for 10 minutes in boiling water, diluted, chilled, filtered, and the product, recrystallized from water, yielded 1.94 grams of *m*-nitro-acet-*p*-toluide, orange-brown crystals, m.p. 96°.

Three grams of aniline in 8 c.c. of conc. sulfuric acid was nitrated with 1 gram of nitroguanidine in 5 c.c. of acid, and the mixture was poured into water, made ammoniacal, filtered, and treated with an excess of ammonium picrate solution. The precipitate, purified by washing with cold alcohol, hot water, and boiling ethyl acetate, yielded 0.402 grams of guanidine picrate, m.p. 311° with preliminary charring, 16% of the theory.

[9] Holleman, Hartogs, and Vanderlinden, *Ber.* 44, 1190 (1911).

Reaction between Cyanamide and Ammonia in Aqueous Solution.

One gram of lime-nitrogen, 5 grams of ammonium carbonate, and 50 c.c. of water were boiled together for 5 minutes. Ammonia came off in abundance, and the solution after filtration gave with ammonium picrate no precipitate whatever. The same amounts of the same materials, heated in a sealed tube for 2 hours at 110°, yielded a solution from which guanidine picrate corresponding to 0.0528 grams of guanidine was obtained.

If a substance like picric acid is present with which guanidine forms a sparingly soluble compound, then the combination of cyanamide with ammonia appears to take place fairly rapidly in ammoniacal solution. Twenty grams of lime-nitrogen was mixed with 50 c.c. of water, and 500 c.c. of water in which 25 c.c. of conc. sulfuric acid had been previously dissolved was added. The solution was filtered, made ammoniacal, again filtered, and allowed to stand over night with the addition of 80 c.c. of saturated ammonium picrate solution. The precipitate, collected the next morning and recrystallized from alcohol, yielded 0.406 grams of guanidine picrate, corresponding to 0.137 grams of guanidine.

Reaction of Nitroguanidine with Ammonia.

One gram of nitroguanidine in a glass capsule was treated with 15 c.c. of strong ammonia water (sp. gr. 0.90), and the mixture was evaporated to dryness on the steam bath. The residue had the appearance of nitroguanidine. After 10 such evaporations with ammonia water, a residue resulted which contained no needle crystals and gave no blue color with a solution of diphenylamine in conc. sulfuric acid. It effervesced with hydrochloric acid, and gave with ammonium picrate a precipitate of guanidine picrate of characteristic properties and melting point. In a similar experiment where the evaporation with ammonia was carried out 15 times, precipitation with ammonium picrate yielded 1.366 grams or 54.6% of the theoretical amount of guanidine picrate. In another where 16 evaporations were made, more rapidly than before, the yield of guanidine picrate amounted to 1.098 grams or 44% of the theory.

Fifteen grams of nitroguanidine and 400 c.c. of strong ammonia were introduced into a tall beaker and the solution was evaporated to dryness slowly on the steam bath during 13 hours. The almost colorless residue smelled of ammonia and, after drying, weighed 8 grams. After extraction with hot alcohol it left 5.2 grams, 40.3% of the theory,

of guanidine carbonate, identified by the picrate, by its effervescence with hydrochloric acid, and by melting point, 205°–207°, after solution in water and precipitation by the addition of alcohol. The alcohol extract of the residue was found to contain a further amount of guanidine carbonate along with urea, m.p. 132° after recrystallization from acetone, identified by mixed melting point with a known sample, by the biuret test, by its nitrate, m.p. 150°–151° (reported 152°), and by its xanthydrol derivative, m.p. 259°–260° (reported 260°–261°). Another experiment with the same amounts of nitroguanidine and of strong ammonia water, in which the evaporation was completed in 8 hours, yielded 7.3 grams of residue from which 5.14 grams of guanidine carbonate, 40.3% of the theory, was obtained. Another in which the evaporation was completed in 6 hours, yielded 7.72 grams of residue, from which 5.30 grams of guanidine carbonate, 41.2%, was obtained.

Preparation of Guanidine Carbonate. Two hundred and eight grams of nitroguanidine (2 mols), 300 grams of ammonium carbonate, and 1 liter of water were heated in the water bath, in a flask equipped with a reflux condenser and a thermometer dipping into the mixture, until the thermometer indicated 65°. Vigorous evolution of gas took place, and it was necessary to shake the flask from time to time to prevent the nitroguanidine from being carried up into the neck. After 10 hours at 65°, everything had gone into solution and the liquid did not deposit crystals on cooling. It was then heated with the flame and refluxed gently for 2 hours to complete the reaction. Ammonia came off in abundance and ammonium carbonate collected in the condenser. Evaporated to dryness on the steam bath, the liquid yielded 172.1 grams of dry crystalline material which was free from ammonium carbonate. This was stirred up with 200 c.c. of cold alcohol, filtered, and rinsed on the filter with more alcohol. The alcohol washings, evaporated on the water bath, yielded 2.4 grams of a mixture of urea and guanidine carbonate from which, by 3 recrystallizations from butyl alcohol, 0.7 grams of urea, 0.58%, was obtained. The residue from the alcohol washing was treated on the filter with just enough water to remove all soluble material, and left 4.5 grams of gritty insoluble matter which, recrystallized once from hot water, yielded 3.5 grams, 4.2%, of melamine. The water solution, diluted with 3 volumes of alcohol, gave a heavy, white, crystalline precipitate of guanidine carbonate. This was filtered off, and dried, and the liquors, evaporated on the steam bath, taken up in water, filtered, and precipitated with alcohol, yielded more of the same material. Total yield of guanidine carbonate, 162 grams, 90% of the theoretical amount.

Guanidine carbonate appeared to dearrange in warm aqueous solution, for a clear solution of the pure material when evaporated on the steam bath gave off ammonia and left a residue of impure guanidine carbonate which contained a few percent of melamine insoluble in water.

Reaction of Nitroguanidine with Amines.

Five grams of nitroguanidine and 15 c.c. of a 33% aqueous solution of methylamine were heated together in a sealed tube in boiling water for 1 hour. The product, treated with ammonium picrate and evaporated to dryness, yielded a residue from which methylguanidine picrate was extracted with alcohol. By recrystallization from alcohol in which it was very soluble, impure methylguanidine picrate, m.p. 193° (reported 200°–201.5°), was obtained, 1.01 grams, 7.3% of the theoretical amount. A few milligrams of material which appeared to be melamine was also present and a mixture of picrates, m.p. 137°–145°, from which nothing definite could be isolated.

In experiments with dimethylamine, no evidence was obtained of dimethylguanidine either as the picrate or as dimethylguanidine platinum chloride which is reported to have a characteristic appearance under the microscope.

Nine and four-tenths grams of aniline, 10.4 grams of nitroguanidine and 125 c.c. of water were boiled together under reflux for 50 hours. The suspended matter, filtered from the hot liquid and recrystallized from alcohol, yielded 2.570 grams of *sym*-diphenylurea, 23% of the theoretical amount. The aqueous filtrate, steam distilled for the removal of aniline and concentrated to a small volume, yielded a few crystals of phenylurea, and, on the addition of ammonium picrate, a very small amount of phenylguanidine picrate which was recrystallized from alcohol and showed a meniscus at 210°, melting completely at 214°.

When 10.4 grams of nitroguanidine and 50 c.c. of aniline were refluxed together in the absence of water for 16 hours, none of these products were obtained. Seven and thirty one-hundredths grams of nitroguanidine was recovered from the mixture and 2.50 grams of other material which appeared to be a mixture of phenylated melamines, for it yielded three fractions one of which did not melt at 300° while the others melted respectively at 189° and at 219°. It was not examined further. No evidence of phenylguanidine was found.

Methylnitroguanidine. A mixture of 15 grams of nitroguanidine

and 55 c.c. of an aqueous 28% solution of methylamine was warmed in a flask under reflux on the steam bath. The mixture effervesced with the evolution of ammonia, and at the end of about 10 minutes, during which time the temperature had risen to about 70°, all of the nitroguanidine had gone into solution. The solution, chilled and filtered, yielded a crystalline mass which was found to consist of a mixture of nitroguanidine with methylnitroguanidine. By extraction with absolute alcohol and recrystallization of the extract, 6.08 grams of methylnitroguanidine was obtained, 35.8% of the theoretical amount. The aqueous filtrate from the chilled reaction mixture was concentrated by slow evaporation for several days; finally carbon dioxide was bubbled through—and crystals of carbonate, m.p. 153°–154°, separated. These effervesced with hydrochloric acid, and, on treatment with ammonium picrate, yielded methylguanidine picrate, m.p. 199.8° (reported 200°–201.5°).

Methylnitroguanidine was obtained in better yield, about 45%, by warming nitroguanidine with an aqueous solution of one equivalent of methylamine (thermometer in the mixture) in the water bath at 65°–70°. When all of the nitroguanidine had gone into solution at this temperature (after about 35 minutes), the solution was chilled, filtered, and worked up with alcohol. Alpha- and beta-nitroguanidine were found to yield identical methylnitroguanidine.

Methylnitroguanidine crystallizes from alcohol in colorless, short, glistening prisms, m.p. 160.5°–161.0°. Molecular weight by the boiling point method in alcohol solution: found 122.5, 121; calculated 118. Nitrogen by combustion: found 46.95%, 47.04%; calculated total nitrogen 47.45%. Nitrogen by nitrometer: found 11.81%, 11.78%; calculated nitro group nitrogen 11.86%.

Methylnitroguanidine dissolved readily in conc. sulfuric acid to yield a colorless solution. When such a solution was warmed, a gas which inflamed a glowing splint began to come off abundantly at 70°, the later portions of gas did not inflame a glowing splint, and gas evolution was complete when 240° had been reached. The acid liquid after cooling was diluted with water, made alkaline with sodium hydroxide, and distilled. Methylamine was identified in the distillate by its picrate, m.p. 205° (reported 207°) and by its chloroplatinate, m.p. 224° (reported 224°). The production of methylamine when methylnitroguanidine is decomposed by hot conc. sulfuric acid is taken as proof that the methyl group, as would be expected, is not attached to the same nitrogen atom as the nitro group.

Although nitroguanidine and methylamine react rapidly in aqueous

solution at 65°–70° to produce methylnitroguanidine, the results are entirely different if the solution is evaporated to dryness on the steam bath. In several experiments, the residues from the evaporation were gummy materials refractory to all attempts at crystallization. On solution in water or alcohol and precipitation with ammonium picrate they yielded a picrate which melted, after several recrystallizations from alcohol, at 160°.

Benzylnitroguanidine. Twelve and one-half grams of benzylamine was diluted with 50 c.c. of water, 12 grams of nitroguanidine was added, and the mixture was warmed at 65° for 40 minutes. The nitroguanidine disappeared, but crystals of a new kind appeared as a froth on the surface of the liquid. The mixture was chilled and filtered, and the solid material, recrystallized from alcohol, yielded 9.16 grams, 40.9%, of benzylnitroguanidine. The aqueous filtrate on evaporation yielded a sticky mass from which a few crystals separated. These, recrystallized from alcohol, melted at 147° and were identified as benzylurea by mixed melting point with a known sample.

Benzylnitroguanidine crystallizes from alcohol, in which it is not very soluble, in colorless needles, m.p. 183.5°. Molecular weight by the boiling point method in alcohol solution: found 193,196; calculated 194. Nitrogen by combustion: found 28.73%, 28.61%; calculated 28.86%. Benzylnitroguanidine chars and heats up when treated with conc. sulfuric acid, and the warm mixture evolves sulfur dioxide. It is less soluble in water than nitroguanidine itself, and requires about 1050 parts of cold water and 200 parts of boiling water for solution.

Other alkyl nitroguanidines were prepared by the method which had been found to work best for the preparation of methylnitroguanidine, and were obtained in yields equal to about 45% of the theoretical amount.

Ethylnitroguanidine, from ethylamine and nitroguanidine, colorless cubes from alcohol, m.p. 147°–148°. Nitrogen by combustion: found 42.01%, 42.33%; calculated total nitrogen 42.42%. Nitrogen by nitrometer: found 10.58%, 10.54%; calculated nitro group nitrogen 10.61%.

n-Butylnitroguanidine, from *n*-butylamine and nitroguanidine, crystallizes from alcohol, in which it is readily soluble, in long prisms. It melts under water at about 65°. If taken up in water at 60°, it is deposited from the cold solution in colorless stout needles, m.p. 84°-85°. Nitrogen by combustion: found 34.84%, 34.90%; calculated total nitrogen 35.00%. Nitrogen by nitrometer: found 8.73%, 8.72%; calculated nitro group nitrogen 8.75%.

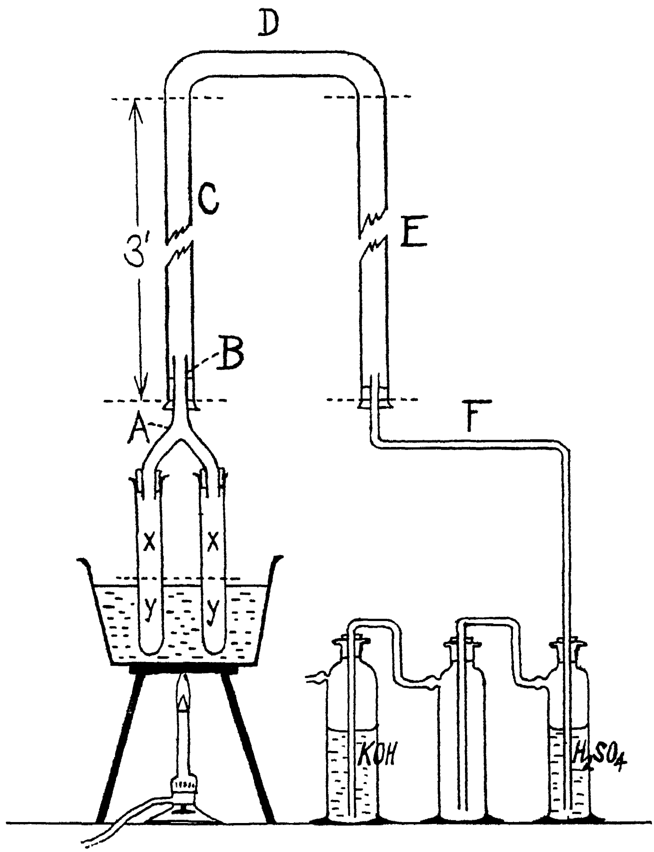
Decomposition of Nitroguanidine by Heat.

A wide-mouth flask was heated in the oil bath at 235°–250°, and 30 grams of nitroguanidine was introduced in small portions at a time, each portion being allowed to decompose before the next portion was added. Fumes containing water and ammonia came off, a sublimate condensed in the upper part of the flask, and a buff-colored residue collected, practically all in one place, on the bottom. About an hour was required for the addition of all of the nitroguanidine, and, in consequence, the first portions of the residue were subjected to the action of the high temperature throughout this period. The residue weighed 7.90 grams, 26.3% of the weight of the original nitroguanidine, and was more deeply buff-colored than the residue of another experiment in which the heating was not continued so long. By extraction with boiling water, cyanuric acid and melamine were obtained from it. The former was identified by the fact that it sublimed without melting and by the preparation of its copper-ammonia complex salt of lilac color and characteristic appearance under the microscope. The latter was sparingly soluble in cold and readily soluble in hot water, from which it crystallized in characteristic rhomb-shaped plates. Its aqueous solution gave a blue-green precipitate with 1% copper sulfate solution, and with 0.1 N silver nitrate a white crystalline precipitate, soluble in ammonia, soluble in considerable boiling water, and soluble in strong silver nitrate solution by heating. The solution in strong silver nitrate deposited on cooling a white crystalline precipitate which, after separation from the liquors, was converted into an amorphous powder by the addition of strong ammonia water and dissolved in a further quantity of the same reagent. The sublimate in the upper part of the flask was found to consist of two kinds of crystals, needles and plates. A portion of each kind was separated by hand-picking; the plates were identified as melamine, while the needles melted at 131° and were identified as urea by mixed melting point with a known sample, m.p. 132°. No urea was found in another experiment where the residue had not been heated for any considerable time after the first decomposition was complete.

In another experiment the nitroguanidine was decomposed in the apparatus represented in the figure.

The nitroguanidine, already crystallized 3 times, was crystallized a fourth time by the rapid cooling of its solution in hot water, and the fluffy mass of fine crystals which resulted was decomposed in 8″ test tubes heated in the oil bath. The vapors passed through the long wide condenser in which the solid material was deposited, and the re-

maining gases passed into wash bottles. The letters and dotted lines of the figure indicate the pieces into which the apparatus was cut after the experiment, thus making possible the separate examination of the residue and of the various portions of the sublimate. Between half a gram and a gram of material was introduced into a test tube



which was connected to the apparatus and heated until decomposition was over. The tube was then removed and another containing fresh nitroguanidine was put in its place. More nitroguanidine was introduced, on top of the residue from the decomposition, into the tube which had been removed, and the tube was again connected with the apparatus and heated in place of some other tube which had been

removed. In each run 6 tubes were used in rotation, and each of these at the end of the run contained the decomposition products from about 20 grams of nitroguanidine. The sublimate condensed almost entirely in the wide tubes; only a very thin film of material was found in the tube, F. A total of 574.5 grams of nitroguanidine was decomposed in 5 runs, as follows:

Weight of Nitroguanidine.	Temperature of Oil Bath.	Weight of Residue.	Residue as percent of Nitroguanidine.
104.5 grams.	233°–235°	27.0 grams.	25.7%
112.0 "	234°	28.7 "	25.6%
104.0 "	234°–235°	24.2 "	23.1%
124.2 "	234°	29.6 "	23.8%
129.8 "	233°–237°	33.0 "	25.4%
574.5 "		142 5 "	24.8%

Gaseous Products. In the first run the gases were passed into water, and the water was found to contain carbon dioxide but neither prussic acid nor cyanic acid. The potassium hydroxide solution which was used in the later runs was found to contain prussic acid by the Prussian blue test, and cyanic acid by Werner's test with copper sulfate, pyridine, and chloroform. The water which was produced during the decomposition condensed in large part in the vertical tube and was found at the end of the experiment in the trap formed by the upper end of the branched tube, A.

The Sublimate. The branched tube, A, contained about 13 grams of solid material from which 8.5 grams of β-nitroguanidine was isolated. This was identified by qualitative tests for nitroguanidine, by conversion into α-nitroguanidine under the influence of strong sulfuric acid, and by measurement of the indices of refraction which were found to be identical with those which have been reported elsewhere. The remainder of the material consisted of melamine along with a small quantity of insoluble amorphous matter which was not examined further. Similar amorphous matter was found in the other portions of the sublimate.

The lower part, B, of the vertical tube afforded only a very small amount of pasty material. When this was extracted with cold water, the extract gave with copper sulfate a black precipitate of copper cyanamide and with ammoniacal silver nitrate a yellow precipitate of silver cyanamide. When a portion of the pasty mass was dried in the oven, it turned slightly yellow, gave off the odors of ammonia and

prussic acid, and yielded a meager residue from which melamine was isolated.

The material in the upper part, C, of the vertical tube gave a distinct test for cyanamide, but was found to consist largely of β-nitroguanidine and melamine, along with a small amount of insoluble amorphous material.

Very little material was deposited in the rest of the condensing train, in the tube, D, only enough material barely to cover its walls. The deposit gave a distinct test for cyanamide and a faint test for nitroguanidine, and was found to consist almost entirely of melamine along with a small amount of amorphous material. The small amounts of material in E and in F were found to be of the same nature except that they appeared to be entirely free from nitroguanidine.

The material scraped out of the upper portions of the 8″ test tubes, after these had been cut in two, weighed 15.5 grams and consisted of cyanamide, melamine, *both* α- and β-nitroguanidine, and a small amount of insoluble amorphous material.

From the entire sublimate 5.5 grams of melamine and 13.0 grams of β-nitroguanidine were isolated.

The Residue. After a preliminary examination of portions of the residue, a method for the separation of the various substances was worked out on the basis of their previously known properties, and the composition of an average sample of the residue was determined with satisfactory accuracy.

A 69 grams sample after an hour of refluxing with 700 c.c. of methyl alcohol left 52.8 grams of material undissolved and yielded a solution from which 10.8 grams of practically pure β-nitroguanidine was obtained on evaporation. The residue from the alcohol extraction was extracted with 3 liters of hot water, and the extract on evaporation yielded 7.0 grams of a mixture of melamine and β-nitroguanidine. The β-nitroguanidine was converted into readily soluble methylnitroguanidine by digesting the mixture on the steam bath for a few minutes with aqueous methylamine solution. The melamine, which was not affected, was filtered from the cold solution, and dried—and weighed 3.22 grams. The residue which remained after the first hot water extraction was again extracted with 3 liters of boiling water. The filtrate on cooling deposited 1.300 grams of ammeline, and on evaporation yielded further 0.950 grams of material which gave only a very faint test for nitroguanidine.

The original residue from the decomposition of nitroguanidine was

slightly buff-colored. The extractions with alcohol and with water had removed colorless substances, and the material which now remained (49 grams) was intensely yellow colored. The presence of mellon in this material was thought to be sufficiently demonstrated by the color, for mellon is the only substance of this series which is colored, and by the fact that the color was discharged by potassium hydroxide solution in accordance with the known behavior of mellon. The residue was now extracted with 2 liters of hot dilute (about 7%) sodium carbonate solution, and the washings, on chilling deposited 7.5 grams of ammeline and, on neutralization with acetic acid, 0.100 gram of ammelide.

The 41 grams of yellow material which remained was treated successively with 2 portions of 650 c.c. of 10% aqueous potassium hydroxide solution, warmed to 90°, and filtered quickly with suction. The filtrates on cooling deposited 4.7 grams of melam, and, on acidification with acetic acid, 28.7 grams of ammelide.

The residue which now remained was of a grayish color. When warmed to boiling with 60 c.c. of 33% aqueous potassium hydroxide solution, it yielded a deep brown colored solution from which only 0.06 gram of undissolved material was removed by filtration. The strongly alkaline filtrate gave an abundant precipitate on cooling. It was acidified completely and yielded 3.600 grams of melam and melem.

The brownish-black bulky material which survived the treatment with strong alkali was identified as paracyanogen. It dissolved to form a brown solution in hot strong alkali and in hot strong sulfuric acid. It was precipitated again by dilution of the sulfuric acid solution. When a small quantity was heated in a hard glass tube, a white sublimate formed at first and disappeared on further heating, a brown sublimate was formed farther up in the tube, the glass was attacked and became grayish, opaque, and filled with little bubbles—and the gas which escaped smelled like cyanogen and burned with a purplish flame. When the gas was passed first into silver nitrate solution and then into potassium hydroxide solution, a white precipitate was produced in the silver nitrate, which showed that the paracyanogen was not entirely pure, and the potassium hydroxide solution was found to contain prussic acid and cyanic acid.

The analysis of the 69 gram average sample of the residue from the decomposition of nitroguanidine is summarized, as follows:

β-Nitroguanidine	14.6 grams.	21.2%
Melamine	3.2 "	4.6%
Ammeline	8.8 "	12.8%
Ammelide	28.8 "	41.7%
Melam	4.7 "	6.6%
Melam and Melem	3.6 "	5.2%
Paracyanogen	0.06 "	0.1%
Mellon and unaccounted for	5.2 "	7.5%

Nitrosations with Nitrosoguanidine.

Two and seven-tenths grams of dimethylaniline was dissolved in a mixture of 20 c.c. of water and 7 c.c. of conc. hydrochloric acid. Two grams of nitrosoguanidine was added and went rapidly into solution forming an orange-red liquid. After 10 minutes crystals began to separate. After half an hour the mixture was chilled and the orange colored crystals were filtered off and rinsed with a little water. Dissolved in water, made alkaline, and extracted with ether, they yielded 1.0 gram of crude product which on recrystallization from benzene with the addition of petroleum ether, gave 0.8 gram of pure *p*-nitrosodimethylaniline, m.p. 85.5°, grass-green leaflets, identified by mixed melting point with a known sample.

Two grams of diphenylamine was dissolved in 20 c.c. of alcohol, 2 grams of nitrosoguanidine and 5 c.c. of conc. hydrochloric acid were added, and the mixture was allowed to stand for three-quarters of an hour. The mixture was then diluted with water, and the precipitate, collected, dried, and recrystallized from ligroin, yielded 0.84 gram of pure diphenylnitrosamine, m.p. 65.5°, identified by mixed melting point with a known sample.

Summary.

A solution of nitroguanidine in strong sulfuric acid apparently contains two substances, one of which gives off nitrous oxide readily on warming, while the other gives off carbon dioxide more slowly on stronger heating. The production of nitrous oxide is not quantitative, but the gases contain elementary nitrogen—as would be expected if nitroamide were present in the solution.

A solution of nitroguanidine in strong sulfuric acid is a suitable reagent for the nitration of certain aromatic substances. After the nitric acid has been removed from such a solution, cyanamide appears to be left.

Similarly, nitrosoguanidine in the presence of hydrochloric acid converts certain aromatic substances into their nitroso derivatives.

The reactions of nitroguanidine in aqueous solution support the belief that it dearranges in this solvent to produce, on the one hand nitroamide and cyanamide, on the other hand nitrocyanamide and ammonia. Thus, it reacts, on the one hand, with ammonia to give guanidine, with ammonium carbonate to give guanidine carbonate in excellent yields, with methylamine to give methylguanidine, and, on the other hand, with ammonia to give urea, with aniline to give phenylurea, with methylamine etc. to give methylnitroguanidine etc., and with benzylamine to give benzylurea and benzylnitroguanidine. Methyl-, ethyl-, *n*-butyl-, and benzyl-nitroguanidine are described.

When α-nitroguanidine is heated to decomposition, it is converted in part into β-nitroguanidine and in part decomposes to yield the products which would be expected from the dearrangement. Water, ammonia, cyanamide, cyanuric acid, urea, melamine, ammeline, ammelide, melam, melem, mellon, and paracyanogen have been found among the products.

CAMBRIDGE, MASSACHUSETTS.

Proceedings of the American Academy of Arts and Sciences.

VOL. 61. NO. 10.—JULY, 1926.

ON THE DISTRIBUTION OF INTENSITY IN STELLAR ABSORPTION LINES

BY CECILIA H. PAYNE AND HARLOW SHAPLEY

ON THE DISTRIBUTION OF INTENSITY IN STELLAR ABSORPTION LINES[1]

By Cecilia H. Payne[2] and Harlow Shapley

1. It is unnecessary to emphasize the significance of the form of absorption lines in the study of problems of atomic structure and the physical constitution of stellar atmospheres. There has been an abundance of theoretical work on line contour, but a remarkable scarcity of quantitative observation. The present preliminary study is aimed to meet, in part, the need for measurements on the broad and strong lines in the spectra of stars of various types.

In general the investigation has been based on objective prism spectra, analyzed with a photographically recording microphotometer. The ease with which a photometric scale can be set up on these plates, available throughout the whole length of the spectrum, and essentially independent of the variability of plates and development, is a decided factor in favor of using objective prism spectra. Other advantages include the efficiency of the objective prism spectrograph and its simple operation. The possible disadvantage of lack of purity is not important, at least in the case of the lines discussed in this communication; the extent to which scattered light affects the true contours of the absorption lines is considered below.

That the results from slit spectrographs are in essential agreement with these slitless spectrograms is shown in Figure 1, where microphotometer tracings of spectra from the two sources are shown. Through the courtesy of Professor W. J. Hussey and Professor R. H. Curtiss, of Ann Arbor, some excellent spectrograms made with the single prism spectroscope at the Detroit Observatory have been sent to Harvard for this comparison. The dispersion is practically the same on the Michigan and Harvard plates. The microphotometer records were made under identical conditions for the two sets of spectra, though the presence of comparison lines on the Michigan plates and the narrowness of the spectra made their analysis more difficult.

2. The work on the Harvard spectrograms has been carried out by the method that was described in the preliminary report (H.B. 805, 1924). The plates were all made with the sixteen-inch refractor,

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[1] The cost of publication of this research has been met with the help of a grant from the Rumford Fund.

[2] National Research Fellow.

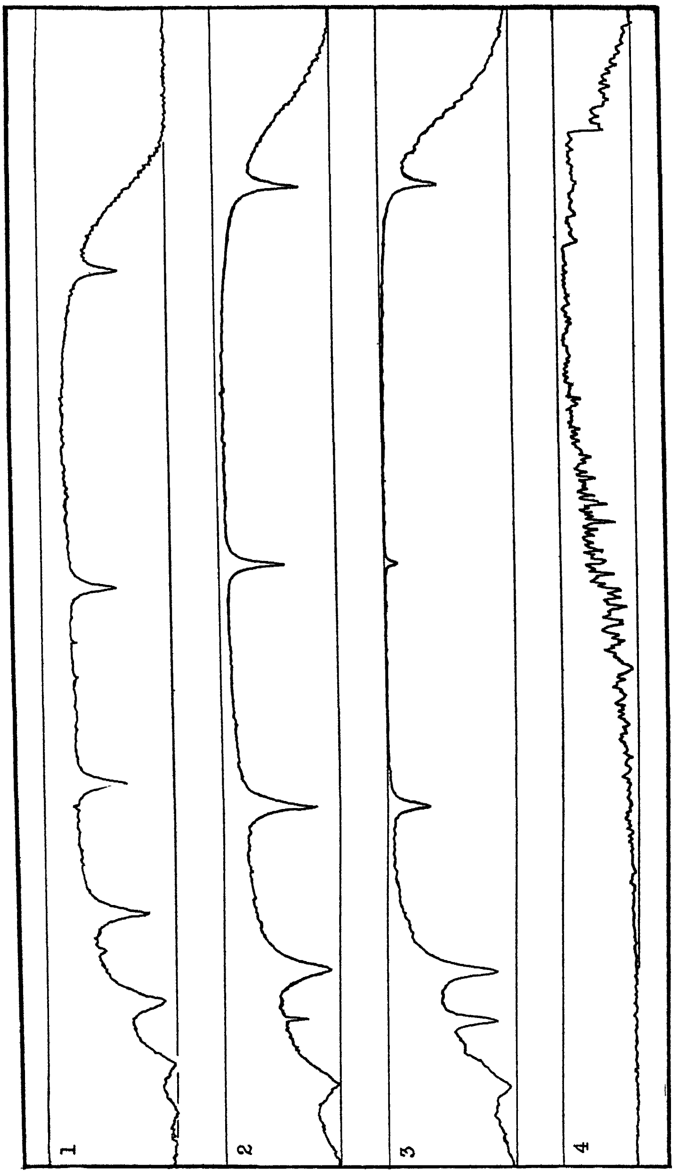

Figure 1.—Microphotometer tracings made from the spectra of four stars. The names of the stars, and the sources of the analyzed spectra, are as follows: (1) α Canis Majoris (Sirius), Harvard objective prism spectrum, (2) α Lyrae (Vega), slit spectrogram, Detroit Observatory, (3) α Aquilae, slit spectrogram, Detroit Observatory, (4) β Pegasi, slit spectrogram, Detroit Observatory. The violet ends of the spectra are to the left.

using two prisms and a special set of apertures. The different apertures provide relative objective areas of 16, 8, 4, 2, and 1, respectively. The apertures are rectangular, and the successive reducing strips are placed perpendicular to the refracting edge of the prism. It is assumed in the discussion that the amounts of light admitted by the apertures are in the same ratio as their areas.

A standard procedure has been adopted in securing the spectrograms. A series of spectra with the several apertures was obtained upon each plate. Focus, clock rate, and exposure time were kept constant over any one series. In general the apertures were used in the order 16, 8, 4, 2, 16. Aperture 1 was omitted in nearly every case, and for a few stars other apertures were also omitted, or found to be useless owing to faintness of the image. Omission of apertures is indicated by notes to Table I.

TABLE I

LIST OF PLATES USED

Plate Number	Star	Spectral Class	Apertures	Remarks
MC 20790	α Lyrae	A0	1, 16a, 8, 4, 2	Ap. 2 not used
20797	α Bootis	K0	1, 16a, 8, 4, 2, 16b	Ap. 1 and 2 not used
20800	α Aquilae	A5	1, 16a, 8, 4, 2, 16b	Ap. 1 and 2 not used
21640	α Cygni	cA2	16a, 8, 4, 2, 16b	
21645	δ Cassiopeiae	A5	16a, 8, 4, 2, 16b	
21646	α Cassiopeiae	K0	16a, 4, 2, 16b	Ap. 16b not used
21721	α Aurigae	G0	16a, 8, 4, 2, 16b	
21722	δ Canis Majoris	cF8	16a, 8, 4, 2, 16b	Ap. 16b not used
21788	β Orionis	cB8	16a, 8, 4, 2, 16b	Ap. 16b not used
21789	ε Orionis	B0	16a, 8, 4, 2, 16b	Ap. 16b not used
21802	α Canis Majoris	A0	8, 16, 4, 2	

The apertured spectra were examined, and any that showed irregularities were rejected. In cases of interference by clouds, whether or not the spectra were visibly impaired, the plates were not measured. Spectra which appeared from experience to be too strong or too weak for satisfactory analysis were also rejected.

3. The present report deals with the spectra of the eleven stars enumerated in Table I. Successive columns contain the plate number, the name of the star, its spectral class, the apertures employed, and remarks.

In addition to the plates enumerated in Table I, the following focus plates were obtained.

Plate	Star	Apertures	Remarks
21648	α Canis Majoris	16, 4, 4, 4, 4, 4, 4, 4, 4, 4, 16	Various focus settings
21803	α Canis Majoris	16, 16, 4, 2, 8, 8, 8, 8, 8, 16	

4. All the plates have been analyzed by means of the Moll thermoelectric microphotometer of Harvard Observatory,[1] which furnishes a photographic record of the plate density. The adjustments of this instrument were made with several ends in view. The analyzing beam of light was kept as narrow as possible, so that no integrating effect should enter into the final result. At the same time it was desired that the total galvanometer deflection—the quantity on which the measures depend—should be of reasonable size; otherwise the errors of measurement would become proportionately too great. Some of the analyzed spectra, especially those of fainter stars, were so narrow that the slit admitting the analyzing beam had to be considerably shortened. This cut down the total light transmitted in the same proportion, and to keep the deflections of the galvanometer of reasonable size, a wider slit, and therefore a wider analyzing beam, had to be used. A compromise was worked out, for each plate, between a narrow analyzing beam and a reasonable galvanometer deflection.

Special precautions were taken to secure the greatest uniformity of conditions possible throughout the analysis of each series of spectra of any one star. At first it was hoped that the whole series of plates could be analyzed under exactly uniform conditions. Owing to the narrowness of some of the spectra, however, it was necessary to introduce the modifications indicated in the preceding paragraph. Even

[1] This instrument was purchased with the aid of the Rumford Fund of the American Academy of Arts and Sciences and the Bache Fund of the National Academy of Sciences.

if all the spectra had been analyzed under precisely the same conditions, experience showed that direct intercomparison between different stars would have been impossible, owing to varying amounts of fog on different plates.

The instrumental settings were made and recorded at the beginning of the analysis of each series of spectra, and when possible were kept untouched throughout the process. The voltage supplying the analyzing beam, and the temperature of the room, were recorded at the beginning and end of each analysis, since both these factors may affect the galvanometer deflection.

The instrumental settings for the different plates analyzed are summarized in Table II. Successive columns contain the plate

TABLE II

Plate Number	Star	Slit Width mm.	Slit Length mm.	Total Deflection scale div.
MC 20790	α Lyr	.25	6.0	77
20797	α Boo	.10	7.0	35
20800	α Aql	.10	7.0	42
21640	α Cyg	.10	5.5	30
21645	δ Cas	.10	4.0	35
21646	α Cas	.40	3.0	45
21648	α CMa	.25	4.0	67
21721	α Aur	.25	5.0	62
21722	δ CMa	.25	5.0	74
21788	β Ori	.25	6.5	91
21789	ϵ Ori	.25	6.0	69
21802	α CMa	.25	6.0	90
21803	α CMa	.25	6.0	85

number, the name of the star, the width in millimeters of the slit producing the analyzing beam, and the total length of that slit. The effective width of the slit producing the analyzing beam differs somewhat from the quantity recorded in the third column. For the three entries .10, .25 and .40, the corresponding effective slit widths are .101, .262, and .385 mm., respectively. The corresponding widths in millimeters of the analyzing beam are 0.010, 0.026, and 0.038, respectively, which are approximately equivalent to .02, .05, and .08 angstroms at Hδ for the dispersion used in this series of plates.

5. *Measurement of microphotometer tracings.*—In addition to the line representing the density of the image at different points along the spectrum, reference marks were inserted by registering a line for "darkness," by interposing an opaque screen in the path of the analyzing beam, and a line for "clear film," by passing the beam through the plate background close to the spectrum, though not close enough to bring it within range of disturbing photographic effects due to the image.

The microphotometer tracings on paper prints were measured with respect to the reference marks. Lines, representing "darkness" and "clear film," were ruled from end to end of the tracing, and across the absorption lines a curve was drawn, completing the curve of the neighboring continuous background. For early type stars this background curve can be drawn without ambiguity; but when the spectrum is rich in lines, the course of the unlined continuous background is largely a matter of judgment.

The quantities measured on the microphotometer tracings are best described by a diagram. Figure 2 represents a wide absorption line,

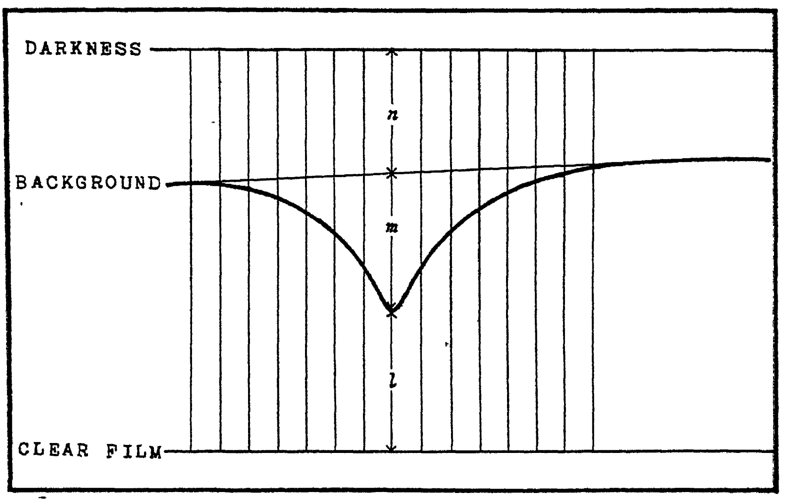

Figure 2.—Diagram of an absorption line, as registered by the microphotometer, showing the method of measuring the tracings. The quantities n ("darkness" to "background curve"), m ("background curve" to "line"), and l ("line" to "clear film") were measured at intervals of five scale divisions, indicated by the vertical lines.

and the various distances that were measured in analyzing such a line. The measures were all made with a half-millimeter réseau scale photographed upon glass, which was laid directly upon the tracing.

6. *Method of reduction.*—The spectra obtained with various apertures provide, as was pointed out in Harvard Bulletin 805, several measures of the intensity at any point of an absorption line. The intensity is compared, in the present paper, with the intensity that the continuous background would have at the same point if the line were not present, which is assumed to be represented by the "background curve" drawn across the absorption line.

The method has the advantage of making a determination separately for each wave length. The difficulties introduced by the varying color sensitivity of the photographic plate are thus avoided. It has, however, the disadvantage that the measured quantity depends to some extent upon the individual judgment of the investigator in drawing the "background curve"—a matter that is simple for Classes B and A, but may prove serious for second-type stars.

The intensity differences, background *minus* line, were determined for several points by direct measurement. The distances, n and $m + n$ for the same wave length in all the spectra of any one series, were obtained from the microphotometer tracings, and were separately plotted against the logarithms of the corresponding apertures. Smooth curves were drawn, joining the plotted points for any one wave length, as in Figure 3. The drawing of the curves is somewhat simplified by considering together several for the same star, remembering that the sections lying between the same abscissae should be roughly parallel. These various curves represent different sections of the familiar characteristic curve for photographic blackening, the logarithm of the aperture being here substituted for the more usual logarithm of the intensity. Differences of intensity between line and background are then readily obtained by interpolating values of n on the curve connecting $m + n$ and aperture, and similarly by interpolating values of $m + n$ on the curve connecting aperture with measured values of n. Each spectrum thus furnished at least one, and sometimes two, values for the intensity difference at any point.

It will be seen from Table IX that for several stars two mean values of line intensity are given, one being the mean of all the measures, and the other the "selected mean." The selected means are obtained by using only points from the more linear portions of the characteristic curve, and by rejecting values derived from microphotometer tracings of exceptional total deflection.

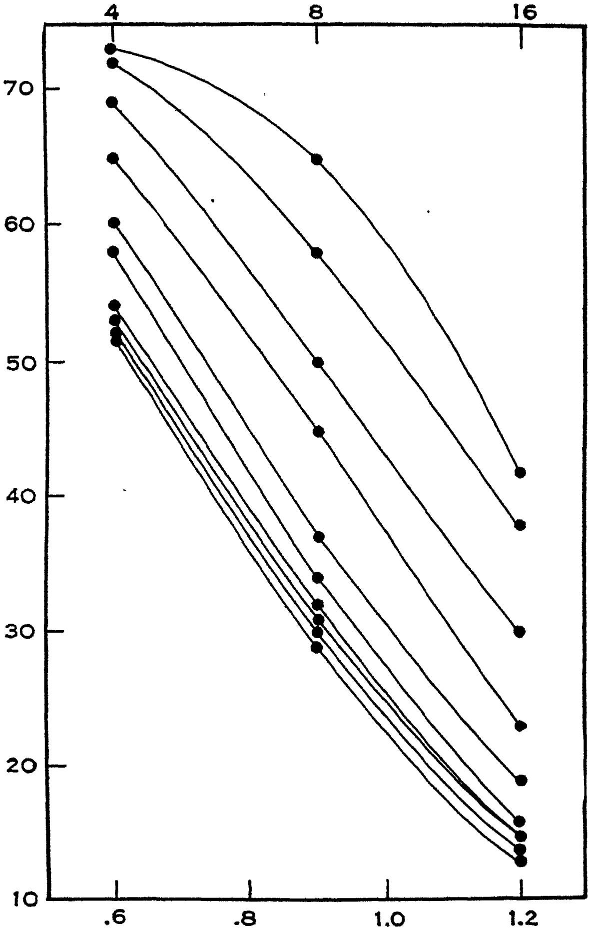

Figure 3.—Relation between galvanometer deflection (representing plate density) and aperture (representing light intensity), from measures of the microphotometer tracings made from the apertured spectra of α Lyrae, MC 20790. Ordinates are galvanometer deflections in scale divisions, abscissae are (above) apertures, (below) logarithms of apertures. Smooth curves are drawn joining the points corresponding to the same wave length, for the three apertures represented.

The intensity drop from background to line is thus obtained in the form log. intensity of background *minus* log. intensity of line. The

change in intensity may readily be converted into stellar magnitudes by dividing the difference of the logarithms by 0.4.

7. The results embodied in the present paper differ so materially from those of some previous workers, that it is of especial interest to examine the accuracy that may be claimed for each stage of the work, and the weight that may be assigned to the results, (Cf. Harvard Monograph No. 1, p. 51). Three stages of the investigation should be considered separately; the plates, (a and b), the microphotometer records (c), and the measures (d).

a. *Accuracy of plates.*—A qualitative test of the reliability of the spectra used is made by examining the reproduction of line detail throughout the whole series made for one star. Figure 4 shows the

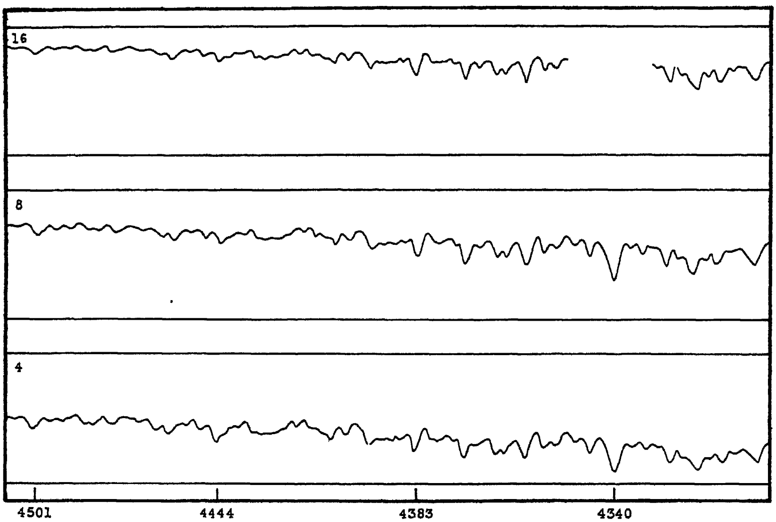

Figure 4.—Microphotometer tracings made from a portion of the Harvard apertured objective prism spectra of δ Canis Majoris, MC 21722. The different apertures used are indicated on the left margin. A few of the more important lines are marked on the lower edge of the diagram.

microphotometer tracings for a portion of the spectrum of δ Canis Majoris, made with apertures 16, 8, and 4. Figure 5 shows a similar series of tracings made from spectra of α Persei, taken with apertures 16, 8, 4, and 2. It may be seen that the reproduction of line detail is satisfactorily faithful, although a few spurious details can be detected.

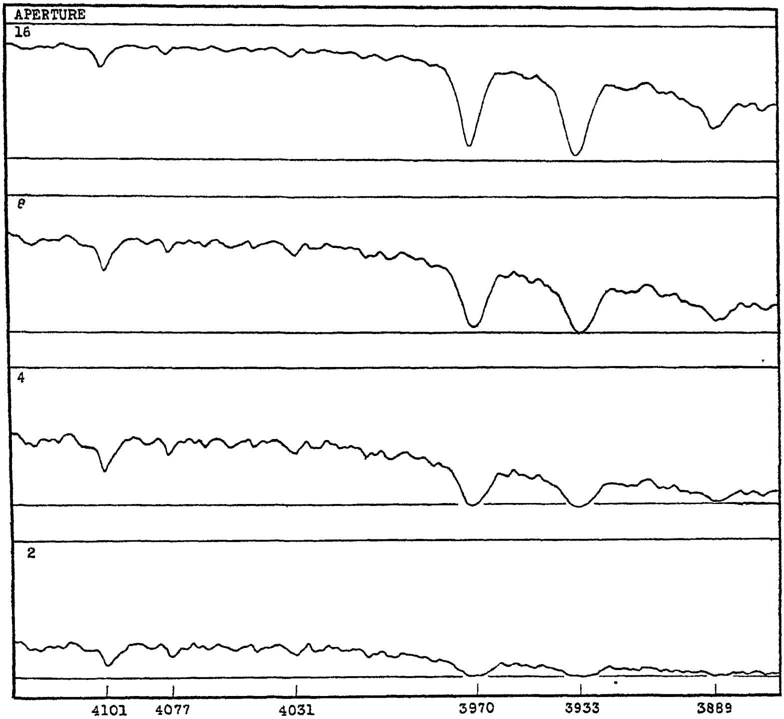

Figure 5.—Microphotometer tracings made from a portion of Harvard apertured objective prism spectra of α Persei. The different apertures used are indicated on the left margin. A few of the more important lines are marked on the lower edge of the diagram.

The best quantitative test of the reliability of the spectra used in this work is the consistency of the numerical results obtained from the different members of a series. From Table IX it may be seen that the residuals very seldom exceed 0.2 m., while the majority are less than 0.05 m.

In specific criticism of the use of the objective prism in line photometry, it has been claimed that the intensity at the line center is affected, and measurably increased, by stray light, and that such an effect is inappreciable for slit spectra. The results of the present work, which deals with lines of various depths, widths, and qualities, are relevant to a discussion of the question, so far as it concerns objective prism spectra.

Presumably the effects of stray light must be greatest in the immediate neighborhood of the stronger portions of the spectrum, and fall off at greater distances from the more heavily exposed parts of the plate. Skylight contributes mainly to plate fog, is uniform over the spectrum and its vicinity, and is eliminated by the use of the line representing "clear film" as a reference base in measuring the tracings.

If the effects of stray light are of importance in the immediate vicinity of the continuous spectrum, they will presumably affect all absorption lines to some extent, and will in particular be greatest for narrow lines. The effects should also be greater for heavily exposed spectra than for the more lightly exposed spectra of the same star. Further, the effects of stray light should appear not only within absorption lines, but also alongside of the spectrum on either edge.

A comparison of the results for δ Cassiopeiae and α Aquilae, both stars of Class A5 (see Table X) shows that the observed line depth is not, in this case at least, a function of line width. The lines of δ Cassiopeiae are both narrower and deeper (that is, they show greater contrast with the background) than those of α Aquilae. The same is true of δ Canis Majoris and Capella; the lines of the former are both narrower and deeper.

The results for apertures 16, 8, 4, and 2 have been compared for all the stars discussed, and the intensity differences between line and background are not appreciably smaller for the larger apertures, which would be the case if stray light were an important factor. Indeed, for α Cygni and β Orionis an opposite effect is shown.

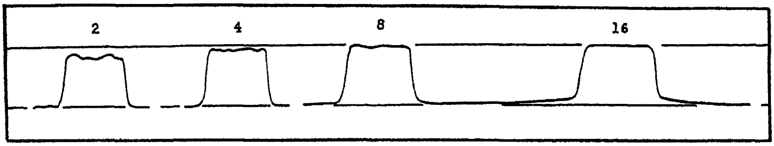

Figure 6.—Microphotometer tracing taken across the spectra of Sirius (MC 21647) made with the different apertures indicated along the upper margin.

To examine the distribution of light at the edges of the spectrum, a microphotometer tracing was made by running MC 21803 (Sirius) through the instrument in a direction perpendicular to the length of the spectra. The resulting tracing is reproduced in Figure 6. Effects

of stray light are not to be found, except for the strongest spectrum. Evidently such effects depend on the heaviness of the exposure, but are not simply proportional to it; they may indicate mainly the "creep" of the overexposed image rather than stray incident light. The point of exposure beyond which stray light begins to be a disturbing factor would have to be determined separately for each plate. In no case is it likely to involve any but the strongest spectrum, and spectra that are strong enough to exhibit the effect are for other reasons not usable. Such measures, in fact, are omitted in deriving the "selected mean," and it would seem that effects of stray light are thus eliminated, while an upper limit may be assigned to their magnitude by comparing the mean derived from all the measures with the selected mean in Table IX. Stray light, although certainly present to some degree, is therefore probably not an important factor in affecting the results of line photometry with the present objective prism spectra.

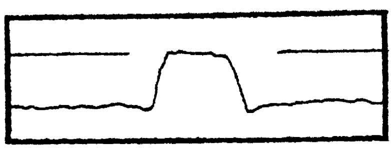

Figure 7.—Microphotometer tracing taken across the spectrum of Vega made with the single prism spectrograph of the Detroit Observatory.

Figure 7 represents the result of a similar test made by taking a microphotometer tracing across an excellent slit spectrogram of Vega that was made with the spectrograph at Ann Arbor. There are no traceable effects of stray light outside the edges of the spectrum, but on the contrary there is a distinct drop in intensity, which may partly be due to an Eberhard Effect. The objective prism spectrum therefore appears to have a slight advantage in this regard, judging from a comparison of Figures 6 and 7.

b. *Effect of focus.*—The effect of poor focus in blurring absorption lines suggests that this factor may enter into the accuracy of the results. It is not possible, in a stellar spectrograph, when working with flat plates, to keep all parts of the spectrum in focus at the same time. Two plates of Sirius were taken for the purpose of examining the magnitude of the effect. The apertures used, and the focus settings, were as follows.

PLATE MC 21648

Spectrum	1a	3a	3b	3c	3d	3e	3f	3g	3h	3i	1b
Aperture	16	8	8	8	8	8	8	8	8	8	16
Setting	17.2	17.2	17.4	17.6	17.8	18.0	17.0	16.8	16.6	17.2	17.2

PLATE MC 21803

Spectrum	1a	1b	2e	3	4	2c	2d	2b	2a
Aperture	16	16	8	4	2	8	8	8	8
Setting	16.6	16.6	16.6	16.6	16.6	16.2	16.4	16.8	17.0

From MC 21648 it is possible to obtain a qualitative estimate of focus effects; MC 21803, including spectra taken with all four apertures, furnishes a quantitative estimate of the magnitude of the focus errors. Microphotometer tracings were made, under uniform conditions, of the spectra of each of the focus plates, and measures were made at the centers of the lines only.

For the plate MC 21648, the observing record book contains the entry: "Frost in center of prism at close." Apparently the frosting resulted in a gradual decrease in the intensity of successive spectra, which is shown, when the spectra are arranged in the order in which they were photographed, by a gradual decrease in n, a quantity that should remain constant for the same aperture, since the edges of the spectrum, the portion where focus would affect the intensity, are not crossed by the analyzing beam of the microphotometer. The progressive change in n is shown in Table III.

TABLE III

Spectrum	3a	3b	3c	3d	3e	3f	3g	3h	3i
n at $H\beta$	13	(12)	13	15	16	16	17	18	17
$H\gamma$	8	8	8	11	9	10	11	10	11
$H\delta$	11	9	10	12	12	14	12	13	15
$H\epsilon$	16	14	17	15	18	19	19	19	20
K	19	17	19	18	20	22	21	22	23
$H\zeta$	27	25	28	29	29	31	31	31	33

That the change in n is progressive and not due to change of focus is shown by arranging the columns in the order of focus setting, 3h, 3g, 3f, 3i, 3a, 3b, 3c, 3d, 3e. No regular change in n is then evident.

The total deflection of the galvanometer is satisfactorily constant for all the microphotometer records of the spectra on MC 21648, excepting 3i, which is rejected for a large voltage drop (0.2 volts),

producing a reduction of four scale units in total deflection. Spectrum 3i is omitted from further discussion. The quantity l must be corrected for change in n, and this may be done by adding to l a quantity equal to the increase in n, since the observed change in n, which should be constant, corresponds to a shift of the whole spectrum, tending to decrease l. The change in l, the distance from "clear film" to line center, as measured on the microphotometer tracings, with changing focus, is shown in Table IV. Values of l are corrected.

TABLE IV

Spectrum	3h	3g	3f	3a	3b	3c	3d	3e
Focus	16.6	16.8	17.0	17.2	17.4	17.6	17.8	18.0
l at $H\beta$	33	36	40	47	49	49	48	43
$H\gamma$	37	38	39	47	47	50	46	47
$H\delta$	32	35	31	40	41	45	43	40
$H\epsilon$	24	26	27	33	33	35	37	31
K	42	44	42	50	50	52	54	47
$H\zeta$	12	14	13	19	18	22	24	20

The line depth is the greatest, and the focus presumably the best, where l is smallest. It appears that spectrum 3h is at best focus.

Table V contains the values of m for different focus settings, in the same form as Tables III and IV. The quantity m requires no correction for change of n. For all the spectra on this plate the K line appears double. The last line of Table V contains the distance, in scale divisions, between the two maxima of the K line on the microphotometer tracing. One scale division corresponds approximately to one Angstrom.

TABLE V

Spectrum	3h	3g	3f	3a	3b	3c	3d	3e
Setting	16.6	16.8	17.0	17.2	17.4	17.6	17.8	18.0
m at $H\beta$	16	16	14	13	13	12	9	11
$H\gamma$	19	18	18	16	15	14	12	13
$H\delta$	22	20	20	19	18	17	15	16
$H\epsilon$	24	22	20	21	22	21	21	19
K	3	3	2	2	2	2	2	2
$H\zeta$	24	23	23	24	25	23	29	28
Width of K	4	4	5	5	7	6.5	9	9

The data of Table V, and the changing width of the K line (thus shown to be an effect of focus) indicate 3h as being the best focussed of the nine spectra. This can also be seen visually from the plate.

The focus plate MC 21803 was similarly analyzed and measured. No progressive weakening of the spectra is shown by this plate, and the measures are therefore uncorrected. For the same plate Table VI shows the change of l with focus setting, in the same form as Table IV.

TABLE VI

Spectrum	2c	2d	2e	2b	2a
Setting	16.2	16.4	16.6	16.8	17.0
l at Hβ	51	52	51	54	53
4481	77	78	79	79	81
Hγ	54	55	56	55	56
Hδ	47	48	51	50	50
Hϵ	39	39	42	43	41
K	62	64	65	65	64
Hζ	22	26	28	28	26
Hη	8	10	12	12	8
Hθ	4	5	4	6	2

Table VII is in the same form as Table V, and represents the change of m with changing focus. Evidently Spectrum 2 c is at best focus.

TABLE VII

Spectrum	2c	2d	2e	2b	2a
Setting	16.2	16.4	16.6	16.8	17.0
m at Hβ	22	22	21	20	19
4481	3	3	2	2	2
Hγ	24	24	23	23	25
Hδ	28	27	26	27	26
Hϵ	31	31	30	28	30
K	6	5	5	4	4
Hζ	36	33	34	33	34
Hη	32	31	30	30	31
Hθ	20	19	20	19	19

By the use of the four apertured spectra that occur on MC 21803 it is possible to evaluate the differences of intensity, produced by the change of focus, directly in stellar magnitudes. The method used in deriving the intensities is the one employed in compiling Table IX. The intensities at the centers of the lines of the various spectra are summarized in Table VIII. It appears that Spectrum 2c is at best focus for lines at either end of the spectrum, and that the curve of best focus moves towards 2b for intermediate lines. The effect is what would have been anticipated on general grounds. The magnitude of

the effect is satisfactorily small, as may be seen by comparing the differences in Table VIII with the residuals in Table IX. Errors arising from bad focus, while they are of appreciable size, do not exceed the errors due to other causes. If the spectra to be analyzed appear upon visual examination to be in good focus, they will probably not give results impaired by serious focus error.

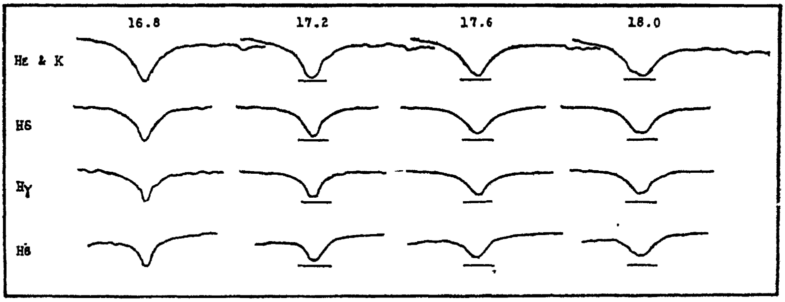

Figure 8.—Microphotometer tracings made from Harvard objective prism spectra of Sirius, MC 21648, to illustrate the effects of focus. Analyses are shown of the five lines indicated on the left margin, for the focus settings given above. The best focus is at 16.8; the short lines below the absorption minima indicate the change in line depth with changing focus. The doubling of the K line, and the increasing distance between the components, is a noticeable effect of focus.

Figure 8 shows, for MC 21648, the lines Hβ, Hγ, Hδ, Hε, and K, for four out of the nine focus settings. The change in line depth, and the blunting of the intensity curve, are at once apparent.

TABLE VIII

Spectrum	2c	2d	2e	2b	2a
Setting	16.2	16.4	16.6	16.8	17.0
Hβ	.53	.53	.51	.49	.47
4481	.13	.13	.09	.09	.09
Hγ	.60	.59	.60	.60	.63
Hδ	.63	.65	.65	.66	.62
Hε	.62	.62	.66	.62	.65
K	.15	.14	.13	.12	.10

c. *Accuracy of microphotometer records.*—As was pointed out in Harvard Bulletin 805, the width of the analyzing beam, which is not in any case greater than one-tenth of an Angstrom, is such that no smoothing effect need be considered at the line center.

In a few cases the same line of the same spectrum was registered twice. The measures made upon the two tracings were always satisfactorily accordant.

The consistency of the results given by the tracings of several spectra of the same star, when photographed with different apertures,

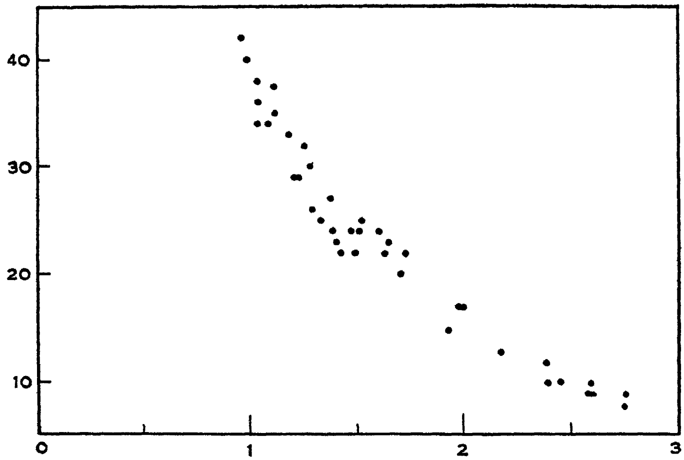

Figure 9.—Test of the consistency of spectra taken with different apertures. Ordinates are distance from "clear film" to "line center" taken from microphotometer tracings of spectra of α Aquilae, MC 20800. Abscissae are the ratio ($l + m$ for one aperture) / ($l + m$ for twice the aperture). The fact that the points lie on a smooth curve indicates that the results are satisfactorily consistent

may be examined by means of the plot shown in Figure 9. Ordinates are values of $l + m$. Abscissas are values of the ratio

$$\frac{(l + m) \text{ for one aperture}}{(l + m) \text{ for twice the aperture}}$$

It is evident that if the points thus derived fall on a smooth curve, the results derived from different tracings of the same spectrum will be mutually consistent. The method of interpolation described in Section 6 may therefore be used in deriving the differences of intensity between line and background.

If the method of Section 6 is to be successfully applied, it is essential that the total range ("darkness" to "clear film") shall be uniform for a single series of tracings. In general the variations in total range do

not exceed three or four scale units, but, for some spectra, occasional changes of eight or ten units have occurred, generally owing to changes of voltage or room temperature.

Under these circumstances, it has been thought best not to attempt to apply any correction for variations in total range, but to reject from the "selected mean" readings from spectra that gave very discordant total ranges.

d. *Accuracy of measures.* In comparison with the errors of the plates and of the microphotometer tracings, the errors in the measurement of the records are of relative unimportance. The chief difficulty, as mentioned above, is that of drawing from fiducial points the reference lines representing the continuous background and the "clear film." The error thus introduced may occasionally amount to one millimeter, or two divisions of the scale.

It is sometimes difficult to decide upon the position of the center of a line, especially when it is wide, without a sharp maximum. This may lead to large residuals for measures on the wings, especially for such lines as Hε and Hζ.

8. The results of the investigation are given in Table IX, which contains, in successive columns, the name of the line, the wave length, expressed to the nearest Angstrom, the mean value of the difference of intensity, background *minus* line, expressed in stellar magnitudes, the residuals, the "selected mean" value of the same intensity difference (see Section 6) and its residuals. The stars are mentioned at the beginnings of their respective records, and are arranged in order of plate number. In the case of stars for which no "selected mean" is quoted, all the values used for the mean conform to the criterion for "selected mean."

TABLE IX

DIFFERENCES OF INTENSITY, BACKGROUND *minus* LINE

Plate and Star	Wave Length	Mean Intensity Difference	Residuals	Selected Mean Difference	Residuals
MC 20790	4877	.11	1, *4*, 4	.11	*4*, 4
α Lyrae	4872	.23	2, *3*, 2	.23	*3*, 2
	4866	.49	*2*, 1, 1	.50	—
	4861 Hβ	.95	*10*, 0, 7, 5	.95	—
	4856	.73	2, *3*, 2, *3*	.73	*3*, 2
	4851	.35	*5*, 5, 2, *3*	.38	2, *1*
	4846	.17	*5*, 3, 3, 0	19	1, 1, *2*
	4840	.07	*2*, 0, 3. *2*	.07	0, 3, *2*

TABLE IX—*Continued*

Plate and Star	Wave Length	Mean Intensity Difference	Residuals	Selected Mean Difference	Residuals
	4358	.11	*6*, *9*, 6, 6, 1	10	*8*, 7
	4354	.23	*11*, *1*, 9, 4	.27	*5*, 5
	4349	.45	*15*, 0, 15, 2	.52	*7*, 8
	4345	83	*8*, *3*, 19, *8*	.86	*6*, 16, *11*
	4340 Hγ	1.43	*6*, 19, *6*, *3*, *3*,	1.62	—
	4336	.92	8, *17*, 5, 3	.92	8, *17*, 5, 3
	4331	.51	*19*, 4, *11*, 14, 11	.55	0, *15*, 10, 7
	4327	.25	*8*, *5*, *5*, 15, 12, *10*	.29	*9*, *9*, 11, 8
	4322	.14	*2*, *4*, *4*, 11, 8, 7	.17	*7*. *7*, 8, 5
	4116	.13	*3*, 4, 9, *8*	.19	*2*, 3
	4112	.32	*10*, 3, 8	.37	*2*, 3
	4109	.60	*15*, 2, 12	.67	*5*, 5
	4105	.92	*17*, 18, *17*, 13, 5	.92	18, *17*
	4102 Hδ	1.60	0, 22, *15*, *5*	1.82	—
	4098	1.11	—	1.11	—
	4095	.72	*17*, 8, 8	.80	0, 0
	4091	.33	*1*, 7, *1*, *3*	.36	4, *4*
	4088	.21	*6*, *1*, *4*, 9	.22	*2*, *5*, 8
	4084	.13	*6*, *3*, *3*, 12	.15	*5*, *5*, 10
	3986	.11	*1*, 1	.11	*1*, 1
	3983	.21	*4*, 1, *6*. 9, 6	.23	*1*, *8*, 7, 4
	3980	45	*10*, 0, *5*, 7, 10	.48	*3*, *8*, 4, 7
	3976	.73	*26*, 7, 14. 4	.80	—
	3973	1.08	*6*, 5. *3*, 2	1.17	—
	3970 Hε	1.68	8, 7	1.60	—
	3967	1.17	—	—	—
	3964	.70	*13*, *8*, 20	62	—
	3960	.56	*21*, 4, 14, 4	.65	*5*, 5
	3957	.28	*11*, 2, *3*, 12	.32	*2*, *7*, 8
	3954	.13	*3*, *3*, *1*, 7	.13	*3*, *3*, *1*, 7
	3936	.05	0, 0	05	0, 0
	3933 K	.23	*1*, *3*, *3*, 7	.23	*1*, *3*, *3*, 7
	3930	11	1, *4*, *4*, 4, 4	.11	1, *4*, *4*, 4, 4
	3899	.55	*5*, 5, 2, 0	.50	—
	3895	.76	1, *1*, 1, *1*	.77	—
	3892	1.03	4, *3*	1.07	—
	3889 Hζ	1.42	—	—	—
	3887	1 10	—	1.10	—
	3884	.78	*3*, 2, *3*, 2	.75	—
	3880	.43	*1*, *1*, *1*, 2	.42	—
	3845	.62	—	—	—
	3842	> .75	—	—	—

TABLE IX—*Continued*

Plate and Star	Wave Length	Mean Intensity Difference	Residuals	Selected Mean Difference	Residuals
	3839	> .75	—	—	—
	3835 Hη	> .75	—	—	—
	3832	.75	—	—	—
	3829	.25	—	—	—
	3826	.16	—	—	—
MC 20797 α Bootis	4340 Hγ	.54	*2*, 1, 1		
	4227 Ca	1.34	2, 2, *3*		
	4215 Sr+	.50	7, 8		
	4101 Hδ	.74	*2*, 3, *2*		
MC 20800 α Aquilae	4877	.00	0, 0	.00	0, 0
	4872	.12	*5*, 5	.12	*5*, 5
	4866	.36	*6*, 6	.30	—
	4861 Hβ	.71	*1*, 1	.70	—
	4856	.45	*5*, 5	.45	*5*, 5
	4851	20	*5*, 5	.20	*5*, 5
	4846	.15	*3*, 2	.15	*3*, 2
	4840	.09	7, 8	.09	7, 8
	4363	.06	*1*, 1	.06	*1*, 1
	4358	.11	*4*, 4	.11	*4*, 4
	4354	.16	*4*, 4	16	*4*, 4
	4349	.21	*4*, 4	.21	*4*, 4
	4345	.39	10, *9*	.49	—
	4340 Hγ	.81	1, *1*	.82	—
	4336	.39	10, *9*	.49	—
	4331	.21	*4*, 4	21	*4*, 4
	4327	.16	*4*, 4	.16	*4*, 4
	4322	.07	0, 0	.07	0, 0
	4318	.01	1, *1*	.01	1. *1*
	4116	.03	4, *3*	.03	4, *3*
	4112	.10	5, *5*	.10	5, *5*
	4109	.23	7, 8	.23	7, 8
	4105	.46	6, *6*	.40	—
	4102 Hδ	.71	1, *1*	.70	—
	4098	50	5, *5*	50	5, *5*
	4095	.23	7, *6*	.17	—
	4091	.10	5, *5*	.10	5, *5*
	4088	.01	1, *1*	.01	1, *1*
	3986	.20	—	.20	—
	3983	.25	0, 0	.25	—
	3980	32	*2*, 3	.30	—
	3976	.43	*3*, 4	.40	—
	3973	.81	1, *1*	.82	—

TABLE IX—*Continued*

Plate and Star	Wave Length	Mean Intensity Difference	Residuals	Selected Mean Difference	Residuals
	3970 Hε	> 1.50	—	> 1.50	—
	3967	.79	*1*, 1	.78	—
	3964	.48	*13*, 14	.35	—
	3960	.25	*12*, 13	.17	—
	3957	.12	*2*, 3	.10	—
	3954	.02	—	.02	—
	3942	.15	—	.15	—
	3939	.22	*2*, 3	.20	—
	3936	.53	*3*, 4	.50	—
	3933 K	.79	*3*, 2	.82	—
	3930	.51	*1*, 1	.50	—
	3927.	.07	5, *5*	.12	—
	3924	.05	—	.05	—
MC 21640 α Cygni	4866	.07	7, *5*, 0, *7*, 10, 0, 0	.07	0, 0, 0
	4861 Hβ	.33	2, 4, *3*, *1*, *3*, *1*, 2	.32	0, 0
	4856	.18	4, *3*, *1*, 2, *3*, *1*	.16	1, *1*, 1
	4345	.11	1, 1, 1, *1*, *1*	.10	0, 0
	4340 Hγ	.63	*1*, 2, *16*, 4, 17, *16*, 2, 7	67	*2*, 3
	4336	.21	1, *1*, 1, *1*	.21	1, *1*
	4105	.16	9, 1, *6*, 4, *4*, *6*	.11	*1*, 1, *1*
	4101 Hδ	.63	17, *3*, *16*, 2, 2	.56	*8*, 9
	4098	.37	13, *2*, 7, 0, *5*	.31	*1*, 1
	3973	.25	*5*, 5, 5, 0, *5*, 0, 7, 2, *5*, 0, *5*	—	—
	3970 Hε	.70	15, 5, *5*, *5*, 22, *8*, *5*, *3*, *5*, *3*	.66	*1*, 1, *1*, 1
	3967	.46	24, *4*, *19*, 14, *1*, *4*, 16, *14*, *16*, 4, 1	.34	7, *2*, 8
	3936	.10	20, 0, *3*, *5*, *5*, 0, 2, *3*, *3*	.06	*1*, 1
	3933 K	.54	13, 1, 7, 1, *10*	.52	3, *5*, 3
	3933	.37	8, 7, *7*, *5*, 8, 8, 0, *10*	.35	*3*, 2
MC 21645 δ Cassiopeiae	4877	.32	*15*, 15	.47	—
	4872	.42	—	.42	—
	4866	.72	*2*, 3	—	—
	4861 Hβ	1.49	7, *7*, 23, *7*	—	—
	4856	.72	*17*, 18	.90	—
	4851	.34	*9*, *7*, 16	.50	—
	4846	.13	*1*, *3*, 4	.17	—
	4354	.31	4, *14*, *16*, 6, 6, 9, 9, *4*	.31	*16*, 6, 9
	4349	.45	5, *13*, 12, 7, 5, 5, *23*	.45	*13*, 7, 5
	4345	.81	1, *1*, 24, *6*, *11*, 16, *21*	.75	5, 0, *5*

TABLE IX—*Continued*

Plate and Star	Wave Length	Mean Intensity Difference	Residuals	Selected Mean Difference	Residuals
	4340 Hγ	1.46	4, 9, *4*, 9, *16*	—	—
	4336	.84	33, 18, *9*, *14*, *9*, *19*	.86	16, *16*
	4331	.55	20, *18*, *5*, 7, *5*, 5, *3*	.50	*13*, 12, 0
	4327	.32	20, *15*, *2*, 13, 3, 0, *17*	.32	*15*, 13, 3
	4112	.34	*2*, *4*, *14*, 8, 1, 1, 6, 1	.30	0, *10*, 5, 5
	4109	.54	*4*, *12*, *22*, 21, *4*, 11, 13	.47	*5*, *15*, 3, 18
	4105	.88	2, *8*, *18*, *13*, 34, 17, *13*, *3*	.75	5, *5*, 0
	4102 Hδ	1.54	1, 6, *4*, 1, *4*	—	—
	4098	.86	*4*, *6*, *11*, 29, *11*, *19*, 26	74	6, 1, 1, *7*
	4095	.53	*13*, *8*, *8*, 22, *3*, *3*, 14	.47	*2*, *2*, 3, 3
	4091	.33	*11*, *8*, *8*, 17, 9, *8*, 9	.29	*4*, *4*, 13, *4*
	3976	.84	9, *4*, *29*, *7*, 56, *17*, *9*. 21	.68	*13*, 9, *1*, *7*
	3973	1.37	*7*, 23, *32*, 13, 1	1.27	*22*, 23
	3970 Hε	2.15	*5*, 15, *5*, *10*, 12	—	—
	3933 K	1.48	*23*, *3*. 2, 22, 2	—	—
MC 21646	4861 Hβ	.25	—	25	—
α Cassiopeiae	4444 Ti +	.31	*6*, 6	.31	*6*, 6
	4340 Hγ	.42	*5*, 5	.42	*5*, 5
	4227 Ca	.83	2, *1*	.83	2, *1*
	4215 Sr+	71	1, *1*	.71	1, *1*
	4101 Hδ	.56	11, *11*,	.56	11, *11*
	3970 Hε	2.50	5, *5*	2.50	5, *5*
	3933 K	2.47	—	2.47	—
MC 21721	4861 Hβ	.43	*16*, *11*, 4, 32, *11*. 4		
α Aurigae	4444 Ti+	.21	9, *14*, *1*, 11, 4, 11, 1		
	4340 Hγ	74	21, 11 1, *7*, *9*, *4*, *12*		
	4326 Fe	.62	13, 5, *10*, 13. 5, *17*		
	4227 Ca	.57	30, *37*, 5, 7, 8		
	4215 Sr+	.36	14, *11*, 1, 4, *6*		
	4101 Hδ	.57	0, *12*, 10, 13, *2*, 5, *17*		
	3976	.53	2, *1*		
	3973	1 14	8, *7*		
	3970 Hε	1.62	13, 5, *17*, 23, *22*		
	3967	1.13	17, *16*		
	3964	62	—		

TABLE IX—*Continued*

Plate and Star	Wave Length	Mean Intensity Difference	Residuals	Selected Mean Difference	Residuals
	3939	.80	0, *5*, *5*		
	3936	1.27	10, *10*		
	3933 K	1.67	5, 3, *10*, 0, 5		
	3930	1.27	10, *10*		
	3927	.76	4, *6*, 1		
MC 21722 δ Canis Majoris	4866	.32	5, 0, *10*, 5		
	4861 Hβ	.61	1, 4, *4*		
	4856	28	4, *1*, *6*, 2		
	4444 Ti+	.76	4, 4, *6*		
	4345	1 12	*7*, 8		
	4340 Hγ	1.12	—		
	4336	1.21	*9*, 9		
	4326 Fe	.78	7, *8*. 2		
	4227 Ca	.70	*10*, 10		
	4215 Sr+	.51	*1*, 1		
	4105	.31	1, *1*		
	4101 Hδ	.86	*1*, *1*, 1		
	4098	.21	6. *6*		
	3970 Hε	> 2.25	—		
	3933 K	> 2.25	—		
MC 21788 β Orionis	4861 Hβ	.22	0, 3, 3, 3, 3, *10*	.25	0, 0, 0, 0
	4481 Mg+	.22	3, 3, 0, 8, 0, *12*	.22	3, 0, 8, 0, *12*
	4471 He	.21	4, 4, 1, 9, 1, *11*	.16	1, 6, *6*
	4340 Hγ	.45	20, *5*, *5*, 15, *5*, *18*	.36	4, 4, *9*
	4101 Hδ	.43	12, *3*, *3*, 12, *3*, *13*	.40	0, 0
	4026 He	.14	3, 1, *2*, 8, *2*, *5*	.12	0, 0
	3970 Hε	.45	10, 5, 0, 7, *5*, *18*	.46	4, *1*, 6, *6*
	3933 K	.17	*2*, 3, 3, 0, *2*, *2*	.18	2, 2, *1*, *3*
	3889 Hζ	43	12, 12, *8*, 11, *8*, *18*	.54	1, 1, *2*
MC 21789 ε Orionis	4861 Hβ	.23	7, *3*, *1*, *3*	.23	7, *3*, *1*, *3*
	4471 He	.31	16, *6*, 1, *11*	.20	—
	4387 He	.24	*2*, *4*, 8, *2*	.20	—
	4340 Hγ	.40	12, *8*, 2, *5*	.35	—
	4116 He	17	5, *2*, *5*, *2*, 3	.17	*2*, *2*, 3
	4101 Hδ	.37	5, *5*, 3, *2*	.36	*4*, 4, *1*
	4097	.17	5, *2*, *2*, *2*	.15	0, 0, 0
	4026 He	.19	1, 1, 1, *4*	.17	3, *2*

TABLE IX—*Continued*

Plate and Star	Wave Length	Mean Intensity Difference	Residuals	Selected Mean Difference	Residuals
	3970 Hε	.32	8, *2*, 5, *10*	.30	7, *8*
	3889 Hζ	.33	2, 14, *6*, *11*	.33	2, 14, *6*, *11*
MC 21803 α Canis Majoris	4877	.12	3, *2*, *2*, 0, *2*, 0	.11	*1*, *1*, 1, *1*, 1
	4872	.30	25, *8*, *5*, 0, *10*, *5*	.25	*3*, 0, 5, *5*, 0
	4866	.56	11, *4*, *4*, 9, *6*, 4	.55	*3*, *3*, 10, *5*
	4861 Hβ	1.02	18, 7, *2*, *10*	.96	*1*, 4, *4*
	4856	.67	13, *12*, 0, 13, *12*, 0	.65	*10*, 2, 15, *10*, 12
	4851	.31	11, *4*, *4*, 1, *4*, 1	.29	*2*, *2*, 3, *2*, 3
	4846	.13	9, *1*, *3*, *3*, 2, *1*, *3*	.12	0, *2* *2*, 3, 0, *2*
	4481 Mg+	.20	5, 0, 0, 0, 0, *8*	.18	2, 2, 2, 2, *6*
	4354	28	2, *6*, 7, *6*, *1*, 4	.31	4, *4*, 1
	4349	.45	5, *3*, 2, *3*, *3*, 2	.45	2, *3*, 2
	4345	.80	10, *5*, 0, *5*, 2	79	1, *4*, 3
	4340 Hγ	1.38	7, *8*, 7, *6*	1.39	6, *7*
	4336	.83	*1*, 4, *6*, *3*, 2, 2	.82	*5*, 3, 3
	4331	.43	*3*, *1*, 4, *8*, 4, 2	.46	1, 1, *1*
	4327	.27	3, *5*, 3, 0, 0, 0	.28	2, *1*, *1*
	4125	.12	10, 7, *5*, *2*, *2*, 3	.11	*4*, *1*, 4
	4121	.20	15, *5*, *5*, *3*, *5*, 2	.17	*2*, *2*, 4
	4116	.42	15, *7*, *10*, 0, *10*, 10	.39	*7*, *7*, 13
	4112	.60	15, *5*, *8*, 15, *8*, *8*	.52	0, 0, 0
	4109	.98	17, *16*, 4, *6*	.97	5, *5*
	4102 Hδ	1.45	12, *13*, 17, *15*	1.46	16, *16*
	4098	1.04	21, *9*, 2, *12*	.97	5, *5*
	4095	.61	29, *6*, *9*, *9*, *6*	.53	*1*, *1*, 2
	4091	.43	14, *3*, *16*, 4, *11*, 9	.37	*10*, *5*, 15
	4088	.24	11, *2*, 7, 1, *4*, *2*	.20	*3*, 0, 2
	4084	.12	10, 0, *7*, 0, *7*, 3	.08	*3*, *3*, 7
	3986	.12	7, 0, *12*, *5*, 10, 2, 0	.12	0, *12*, *5*, 10, 2 0
	3983	.25	7, *2*, *7*, *7*, 0, 2	.25	*2*, *7*, *7*, 0, 2
	3980	.42	15, *2*, *10*, 12, 0, *7*	.42	*2*, *10*, 12, 0
	3976	.66	22, *2*, *5*, 0, *18*	.58	5, 2, 7, *10*
	3973	.86	*22*, 13, 8	.97	3, *2*
	3970 Hε	1.47	11, *11*, 18. *11*	1.45	*11*, 20, *9*
	3967	1.10	20, *8*, 2, *15*	1.02	0, 10, *7*
	3964	.70	27, *3*, *10*, *5*, *15*	.64	*5*, *2*, 3, *7*
	3960	.47	23, *2*, *5*, 3, *7*, *10*	.43	2, *1*, 7, *3*, *6*
	3957	.33	24, 0, *6*, 0, *8*, *8*,	.28	5, *1*, 5, *3*, *3*
	3954	.23	19, 4, *6*, *13*, *11*	.16	11, 1, *6*, *4*
	3933 K	.18	12, 2, *6*, 4, *3*, *6*	.17	3, *5*, 5, *2*
	3889 Hζ	1 48	7, *9*, 17, *16*	1.55	—

9. Table X contains a summary of the results, for line centers only. Successive columns give the name of the star, the spectral class, the absolute magnitude, and the drop in magnitudes from background to line center, for the spectrum lines mentioned at the heads of the columns. The greater line depth for absolutely brighter stars, at least among those of the second type, is especially to be noted.

TABLE X

DROP IN INTENSITY, FROM BACKGROUND TO LINE CENTER, FOR ELEVEN STARS, EXPRESSED IN STELLAR MAGNITUDES

Star	Class	M	Hβ	Hγ	Hδ	Hε	K	4227	4215
ε Ori	B0	—	.23	.40	.37	.32	—	—	—
β Ori	cB8	—5:	.22	.45	.43	.46	.17	—	—
α Lyr	A0	0.6	.95	1.43	1.60	1.68	.23	—	—
α CMa	A0	1.2	.96	1.39	1.46	1.47	—	—	—
α Cyg	cA2	—4:	.33	.63	.63	.70	.54	—	—
α Aql	A5	2.4	.71	.81	.71	1.50	.79	—	—
δ Cas	A5	1.6	1.49	1.46	1.54	2.15	1.48	—	—
δ CMa	cF8	—3:	.61	1.12	.86	>2.25	>2.25	.70	.51
α Aur	G0	0.0	.43	.76	.57	1.62	1.67	.57	.36
α Boo	K0	—0.3	—	.54	.74	—	—	1.34	.70
α Cas	K0	0.0	.25	.42	.56	2.50	2.47	.83	.71

10. The material contained in Table X is reproduced in Table XI, where the intensity at the line center is expressed in terms of percentage of the background intensity, instead of in stellar magnitudes. The "background intensity," as defined in Section 6, is the intensity that the background would have if the line were not present. It is noteworthy that, for the great majority of the lines, the residual intensity at the line center is greater than 30 per cent of the background intensity.

11. The material presented above constitutes the first systematic study of the contours of strong absorption lines. In view of the preliminary nature of the work the discussion has been devoted for the most part to presentation of method. Extended discussion seems at present to be premature, and only a few points need be mentioned.

Probably the chief interest of Table X lies in the result that the maximum intensity drop from background to line recorded for any of these stars is 2.50 magnitudes, corresponding to a light loss of

TABLE XI

RESIDUAL INTENSITIES AT LINE CENTERS, EXPRESSED AS PERCENTAGES OF BACKGROUND INTENSITY

Star	Class	Hβ	Hγ	Hδ	Hε	K	4227	4215
ε Ori	B0	81	69	71	74	—	—	—
β Ori	cB8	82	66	67	65	86	—	—
α Lyr	A0	42	27	23	21	81	—	—
αCMa	A0	41	28	26	26	—	—	—
α Cyg	cA2	74	56	56	52	61	—	—
α Aql	A5	51	47	51	25	48	—	—
δ Cas	A5	25	26	24	14	26	—	—
δ CMa	cF8	57	36	45	<13	<13	52	63
α Aur	G0	67	50	59	22	21	59	72
α Boo	K0	—	61	51	—	—	29	52
α Cas	K0	79	68	60	10	10	47	52

ninety per cent. Except for the supergiant cF8 star and the Ca+ absorption for α Cassiopeiae and Hε for δ Cassiopeiae, the light remaining at the center of the line is at least fifteen per cent of the background intensity. On the average for all these strong absorption lines there is something like twenty-five per cent of the background light remaining at the center of the lines. The significance of these residual intensities will be discussed in a later publication, when the forms of the lines as shown by the data of Table IX will also be considered.

For the wider lines, especially those that are strong and heavily winged, the intensities derived in this paper are probably of the right order. Probably, however, the dispersion used is too small to reproduce satisfactorily the detail at the centers of lines as narrow as those of such stars as α Cygni and β Orionis. The difficulty introduced does not involve inaccuracy of plates, microphotometer, or process of measurement; it is concerned solely with the fact that the spectral region examined is so narrow that, with the dispersion used, the grain of the plate is not fine enough to reproduce the spectral detail. The same difficulty would prevent any recognition of the double reversal of the solar H and K lines, if they were studied with the present dispersion.

Whatever the dispersion used, the same qualification must be made in discussing the results; probably the dispersion would have to be

greatly increased before the measured effective line depth becomes much greater for narrow line stars.

Relative effective line depth, derived from numerous spectra made with the same dispersion, is still, however, of considerable significance. It permits us to recognize differences of surface gravity, and to form an idea of relative chromospheric depths for different classes of stars.

Summary

1. The investigation deals with the determination of the depth and contour of prominent absorption lines in the spectra of stars of various classes.
2. The spectra used were made with the 16-inch refractor of the Harvard Observatory, using two prisms and a special set of apertures.
3. Results are presented for eleven stars, of spectral class ranging from B0 to K0.
4. The spectra were analyzed under uniform conditions by means of the Moll thermoelectric microphotometer. The resolving power of this instrument is such that no integrating effect need be considered in discussing the results.
5. The microphotometer tracings were measured with reference to fiducial lines representing "darkness" and "clear film," and to a line, representing the continuous background, drawn across the absorption lines.
6. The intensity drop from continuous background to line was deduced graphically from the measures.
7. The accuracy of the results is discussed in detail.

   a. The reliability of the plates, as judged from qualitative reproduction of detail, and from the consistency of the numerical results, is satisfactory. Effects of stray light are of negligible magnitude, and in this respect slit spectra appear to have no advantage over objective prism spectra.

   b. Effects of poor focus are measurable, but small. Spectra that are in such poor focus as to cause appreciable inaccuracy would be rejected from visual inspection.

   c. The accuracy of the microphotometer tracings is in general satisfactory. Tracings showing abnormal deflections from "darkness" to "clear film" are not susceptible of correction, and are omitted in deriving results.

   d. The measures upon the tracings are also of satisfactory accuracy.

8. The differences in intensity between the continuous background and various points along the line contour are tabulated for the eleven stars under discussion.

9. The general results for the intensities at the centers of lines show an interesting relation to absolute brightness; the brighter stars have, in general, lines that cut more deeply into the background. A result of considerable interest is that the average residual intensity in the strong wide absorption lines is more than 30 per cent of the background intensity.

Proceedings of the American Academy of Arts and Sciences.

Vol. 61. No. 11. August, 1926

CHANGES DURING THE LAST TWENTY YEARS IN THE WORLD'S SPEED RECORDS OF RACING ANIMALS.

By A. E. Kennelly.

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Presented January 13, 1926. Received January 23, 1926.

In July 1906, the author presented a paper to the Academy[1] entitled "An Approximate Law of Fatigue in the Speeds of Racing Animals." That paper will be referred to, in what follows, as the "earlier paper," or the "1906 paper." This paper is offered as a sequel. It attempts to bring the subject up to date, from January 1906 to January 1926.

A brief summary must first be given of the contents of the 1906 paper. The world's racing records were presented, as to both distances and running times, in eight classes of athletic speed events; namely, for horses in three gaits—trotting, pacing and running; likewise for men in five gaits—walking, running, rowing, skating and swimming. It was shown that, denoting the length of the race in meters by L, the time occupied by the winner, in seconds, by T, and the mean speed of the winner over the course, in meters per second, by V, if any one of these three quantities were plotted as ordinates, on ordinary uniform squared paper, against either of the two remaining quantities as abscissas, the graph was a certain curve, not easily interpreted on simple inspection. The mean speed V diminishes when either the distance L or the time T is increased. If, however, these world records are plotted on "logarithm paper," then approximate straight lines are evolved in each and all of the six graphs suggested (T against either L or V, L against either T or V, and V against either L or T). This straight-line relation between the variables, on logarithm paper, shows that there is a set of simple exponential relations between the three variables in each class of events, or that one varies as a certain power of either of the two others.

Moreover, curiously enough, the approximate straight lines on "log paper" representing the eight different classes of events, are all substantially parallel to each other. This means that there is not only a certain approximate law of "fatigue," in one and the same class of races, whereby the speed V falls off according to certain powers of the course length L, or of the running time T; but the same approximate law of fatigue underlies all of the eight classes of races, alike for

[1] Bibliography 4.

bipeds and quadrupeds, and for all the various gaits investigated of each. The mean speed V of men swimming is very different from say that of horses trotting; but the exponential relation between the diminution of speed, with increasing L or increasing T, is the same, or at least substantially the same, in both cases.

The actual relations deduced were as follows, with reference to any events in the same class

$$T \fallingdotseq \frac{L^{9/8}}{c} \qquad \text{and also } T \fallingdotseq \frac{c^8}{V^9} \qquad \text{seconds} \qquad (1)$$

$$L \fallingdotseq c^{8/9}\, T^{8/9} \qquad \text{“ \quad “} \quad L \fallingdotseq \frac{c^8}{V^8} \qquad \text{meters} \qquad (2)$$

$$V \fallingdotseq \frac{c}{L^{1/8}} \qquad \text{“ \quad “} \quad V \fallingdotseq \frac{c^{8/9}}{T^{1/9}} \qquad \frac{\text{meters}}{\text{second}} \qquad (3)$$

where $\fallingdotseq$ represents approximate, as distinguished from strict equality, and c is a constant for each particular class of events. Consequently, from (1), doubling the length L of a race increases the time T approximately 118 per cent; while doubling the mean speed V, cuts down the racing time 512 times.

From (2), doubling the time T of a race allows of approximately 85 per cent increase in its length L; while doubling the velocity V, cuts down the length L 256 times.

From (3), doubling the distance run L, brings down the mean velocity V, over the course, by approximately 9.3 per cent; while doubling the racing time T, cuts down the velocity V 7.4 per cent.

It was also shown that so far as the evidence from the behavior of many racers over different lengths of course could be applied to the speed performance of any one racer in a single contest, it was probable that a record maker's best speed should be as nearly as possible uniform, from start to finish, and just such as to bring him to muscular exhaustion at the goal. Any slackening of speed, on the one hand, or acceleration of speed on the other, at any part of the course, was probably destructive of his best performance.

It was likewise pointed out that the records best open to future attack by athletes, were probably those which fell on the defective side of the straight lines, in the various graphs accompanying the paper.

The world's records referred to, were taken from the pages of "The World Almanac and Encyclopedia" for 1906, and preceding years.

They are tabulated by events in the 1906 paper. There are 49 for horses and 216 for men, excluding bicycling records.

In this paper, 133 new records up to Jan. 1st, 1926 are reported, 32 for horses and 101 for men. These are tabulated in the following pages. The preceding records are not repeated in the tabulation; but the various following diagrams contain both the unbroken earlier as well as the later records, in graphical representation.

The straight lines drawn on the diagrams of this paper, as representing the selected approximate standard exponent for each event, are located in the same positions as in the corresponding diagrams of the earlier paper. In this way, the bearings of the new records can be more fairly judged than if the straight lines were drawn to suit the new records in each case. Exceptions, however, should be noted in the records of swimming and of bicycling, to which reference will be made later on.

The new records are taken from the latest numbers of the "World Almanac and Book of Facts," of New York, with a few additions from "Whittaker's Almanac" of London. They may be presented in the same order as in the earlier paper.

Horses Trotting

Table I gives the three lowered records for the 1-mile, 3-mile and 5-mile events, (116.75, 250.25 and 728.25 seconds), made in 1922, 1925, and 1919 respectively. There is also a new 7/8-mile event. All the records, new and old, are plotted on the logarithmically ruled sheet Fig. 1, making two traverses over the same. Here time T in seconds is plotted against the race length L in meters. The straight lines are placed as drawn on the corresponding diagram of the earlier paper. It will be seen that, up to and including 30 km. of distance, the agreement of the records with the straight lines is good. Beyond 30 km., the times are long, and the average speeds are low. The straight lines are drawn at a slope of 9 units in ordinates to 8 similar units in abscissas. These lines therefore make with the axis of abscissas an angle of 48° 22′, whose tangent is 9/8. This corresponds to a relation between T and L represented by the equation:

$$T = \frac{L^{9/8}}{33.9} \qquad \text{seconds} \quad (4)$$

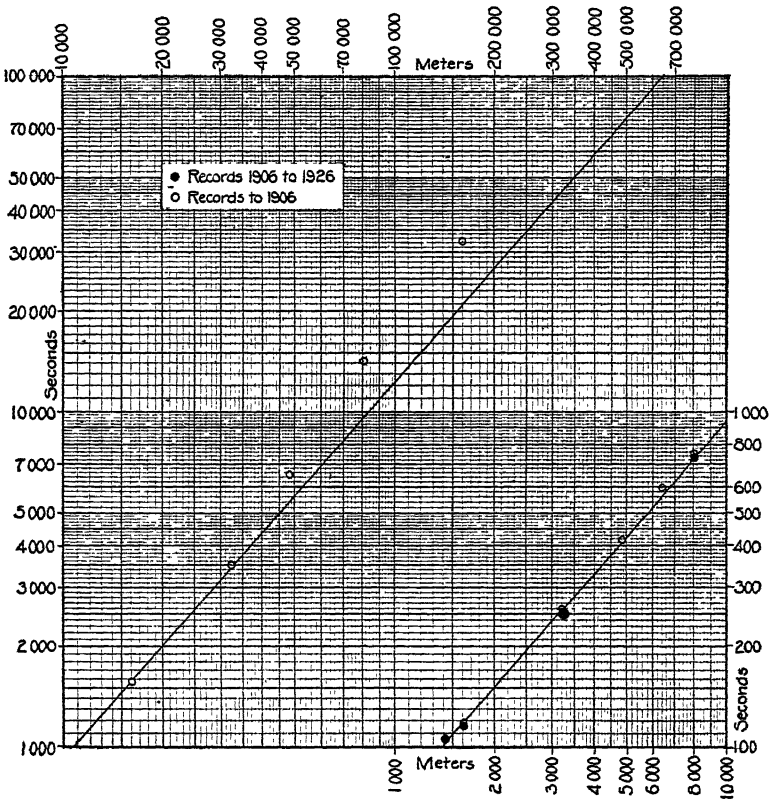
The times T' seconds, computed from formula (4) for the distances L of these new records, are given in the Table. These computed

TABLE I.

TROTTING-HORSE RECORDS FROM 1906 TO 1926

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs
1925	⅞ mile	106.25	1408.2	13.25	2 0263	3.1487	1.1224	102.9	−3 35
1922	1 "	116.75	1609 3	13.786	2 0737	3 2066	1.1329	119 5	+2.75
1925	2 "	250 25	3218.7	12.86	2.3984	3 5077	1.1093	260 7	10 45
1919	5 "	728.25	8046.7	11.05	2.8755	3 9056	1.0301	730 8	2 55

FIGURE 1. WORLD'S RECORDS HORSES TROTTING



times are 119.5, 260.7 and 730.8 seconds respectively. The new records are better than these by 2.75, 10.45 and 2.55 seconds respectively. The earlier records were 118.5, 257 and 750.75 seconds respectively. The principal change has been in the 5-mile record, which, instead of being 20 seconds worse than the computed time T', has become 2.55 seconds better than T′.

The mean speeds V over the courses in the various events, are all collected for ready comparison into one diagram—Fig. 11. It will be seen that, up to 30 km. of distance L, the points for trotting horses fall on a fairly good line, which corresponds to

$$V = \frac{33.9}{L^{1/8}} \qquad \text{meters per second} \quad (5)$$

Horses Running

Table II shows the world's records made by running horses since 1906, and the dates at which they were respectively established.

The records, old and new, are collected in Fig. 2, a logarithmically ruled diagram. The unbroken straight line is located as in the corresponding diagram of the 1906 paper. It will be seen that for distances shorter than 1000 meters, the points lie above this line, or have excessive time. They represent therefore lower racing speeds than pertain to the straight-line law. These deviations of the short races from the line may be explained by starting inertia, or the delay caused in acceleration to full speed, at and near the start. For distances beyond 1000 meters, the records prior to 1906 fall in most cases close to the unbroken straight line, corresponding to the relations

$$T = \frac{L^{9/8}}{42.4} \qquad \text{seconds} \qquad (6)$$

and

$$V = \frac{42.4}{L^{1/8}} \qquad \frac{\text{meters}}{\text{second}} \qquad (7)$$

The new records, beyond 1000 meters distance, lie in most cases below the earlier straight line. A new and broken straight line has therefore been drawn, below and parallel to the first, and passing very nearly through the new 2012-meter event. This broken line for the new records, corresponds to the relations:—

$$T = \frac{L^{9/8}}{43.4} \qquad \text{seconds} \qquad (8)$$

and

$$V = \frac{43.4}{L^{1/8}} \qquad \frac{\text{meters}}{\text{seconds}} \qquad (9)$$

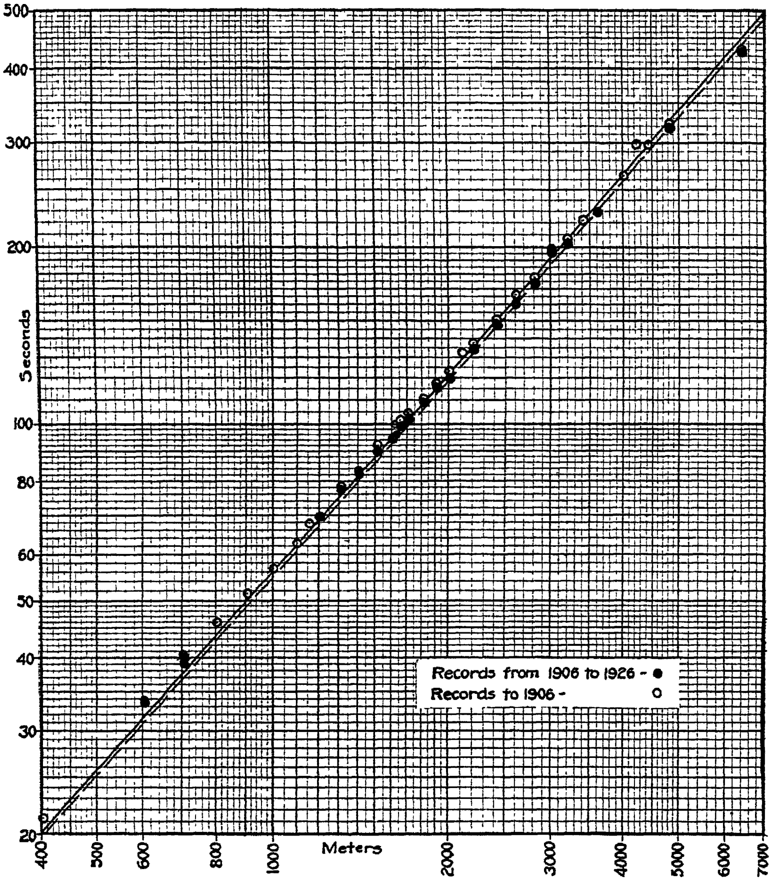
This change of the coefficient c from 42.4 to 43.4, represents an apparent average increase of racing speed since 1906, amounting to 2.3 per cent. It might be accounted for by an improvement in the record-making ability of running horses during the past twenty years. Such an improvement in the performance of horses is not a new phenomenon. As was pointed out in the earlier paper, attention has been called to continuous improvements in the speeds of trotting and of running horses, by the late Prof. F. E. Nipher, in a communication presented to the St. Louis 1903 meeting of the American Association

TABLE II.

Running-Horse Records from 1906 to 1926.

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
1906	3/8 mi.	33.5	603.5	18 02	1.5250	2.7807	1.2557	31.69	−1.81
1916	7/16 "	39.0	704.1	18 05	1.5911	2.8476	1 2565	37.68	−1.32
1914	3/4 "	69.6	1207	17.34	1 8426	3.0817	1.2391	69.10	−0 50
1919	13/16 "	77.4	1307.6	16.89	1.8887	3.1165	1 2278	75 63	−1.77
1906	7/8 "	82.0	1408	17 17	1.9138	3.1486	1 2348	82.19	0 19
1922	15/16 "	90	1509	16.765	1.9542	3.1787	1.2245	88.84	−1.16
1923	1 "	95.4	1609	16.865	1.9795	3 2066	1 2271	95.50	0 10
1925	1780 yds.	98.0	1627.5	16.61	1.9912	3 2115	1 2203	96.72	−2 28
1923	1800 "	99.4	1646	16 56	1.9974	3.2164	1.2190	98.00	−1 40
1908	1810 "	100.8	1655	16 42	2.0035	3 2188	1.2153	98 56	−2 24
1923	1.0625 mi.	102.2	1710	16 73	2.0095	3 2330	1.2235	102 2	0
1924	1.125 "	108.8	1810 5	16 64	2.0366	3.2578	1.2212	109.0	0.2
1920	1.1875 "	115.6	1911	16.53	2.0630	3.2813	1.2183	118.6	3.0
1913	1 25 "	120	2012	16.77	2.0792	3.3036	1 2244	122 8	2.8
1920	1.375 "	134.2	2213	16 49	2.1278	3.3450	1.2172	136 7	2.5
1920	1.5 "	148 8	2414	16.22	2.1726	3.3827	1 2101	150.7	1.9
1920	1.625 "	160.8	2615	16 26	2.2063	3.4175	1 2112	168.8	8.0
1924	1.75 "	174.6	2816	16.13	2.2420	3.4496	1.2076	179.3	4.7
1925	1 875 "	196.8	3018	15.33	2 2940	3.4797	1.1857	193.7	−3.1
1920	2.0 "	201.8	3219	15.95	2.3049	3.5077	1.2028	208.4	6.6
1922	2 25 "	229 0	3621	15 81	2.3598	3.5588	1.1990	237 8	8 8
1907	3.0 "	319.0	4828	15.14	2.5038	3.6838	1.1800	328.8	9 8
1912	4.0 "	430.8	6437	14.94	2.6343	3.8087	1.1744	454.4	23.6

FIGURE 2. WORLD'S RECORDS RUNNING HORSES



for the Advancement of Science. According to the Nipher curve of past performance, the hypothetical increase in speed of running horses referred to the mile record, would amount to approximately 2.1 per cent in the period from 1903 to 1923. Too much confidence should not however be placed on the apparent precision of this agreement, because we are not comparing two records differing in time by just twenty years; but two groups of records, made at various dates, plotted at dates twenty years apart.

While there seems to be a small similar improvement in the new new records of Fig. 1 for trotting horses, there are only three of them to judge from, and the amount of such hypothetical improvement for the speeds of trotting horses is more doubtful.

Horses Pacing

Only five lowered pacing records have been found (½, 1⅛, 1¼, 3 and 5 miles). They are given in Table III, and are plotted in Fig. 3, along with the earlier records, and the earlier straight line. It is difficult to say from this Figure, whether there has been any appreciable improvement in pacing speeds since 1906. The straight-line corresponds to the equations:

$$T = \frac{L^{9/8}}{34.38} \qquad \text{seconds} \qquad (10)$$

$$V = \frac{34.38}{L^{1/8}} \qquad \frac{\text{meters}}{\text{second}} \qquad (11)$$

Summing up the conclusions relating to the new world's records of horse racing, we may say that there appears to have been a small but distinct improvement in the speeds of running horses since 1906, and possibly also of trotting horses, but it is doubtful if any change has been shown in the speeds of pacing horses. The straight TL lines on logarithm paper of these three classes of events are the same as they were in 1906, except that of running horses which has moved down slightly. All these lines are parallel, or substantially so, thus showing the same law of fatigue, or of diminution of course speed with respect to distance covered.

As was pointed out in the earlier paper, it may be noted that the precision of conformity between the events and the straight-line law on log paper is greater in the horse races than in men races.

Men Running

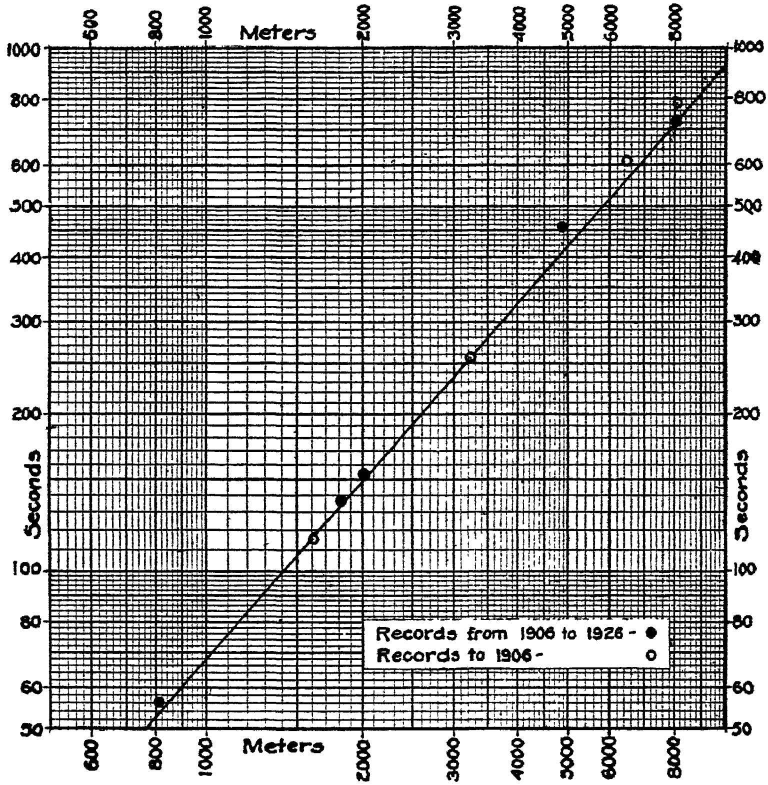
There have been about thirty new world's running records made since 1906, of which about half are improvements on earlier records, and half new records made for distances not listed in the earlier series. These new records are given in Table IV. The entire series of old and new records are plotted in Fig. 4, and they cross this Figure three times, first in the upper left-hand area, then across the middle, and last in the lower right-hand area. These may be described as the top-, middle- and bottom-line sections. By the use of these three

TABLE III.

PACING-HORSE RECORDS FROM 1906 TO 1926

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
1916	½ mi.	55.75	804.6	14.43	1.7462	2.9056	1.1594	54.01	– 1 74
1925	1⅛ "	137 5	1810.5	13.17	2.1383	3.2578	1.1195	134.5	– 3.0
1925	1¼ "	153.5	2011.7	13.10	2.1861	3 3036	1.1175	151.5	– 2.0
1909	3 "	451.5	4828	10.695	2.6547	3 6838	1.0291	405 5	—46.0
1917	5 "	722.75	8047	11.13	2.8590	3 9056	1.0466	720.3	2.45

FIGURE 3. WORLD'S RECORDS HORSES PACING



parts of one and the same straight line, all distances are accommodated from 20 meters to 100 kilometers, and all times from 3 seconds to 27,000 seconds.

It will be seen that in the top section, the events depart from the line, upwards, except the 91.4 meter event (100 yards) which is now a little below the line. These deviations, at the very short sprints below 90 meters, may be attributed to starting inertia.

In the middle section, the events swing from one side of the line to the other. They are below the line from 100 to 400 meters. This means that the times are relatively short over those distances. It is generally admitted that the stress in, and physical exhaustion from, these races between 100 and 400 meters, are greater than over any

TABLE IV.

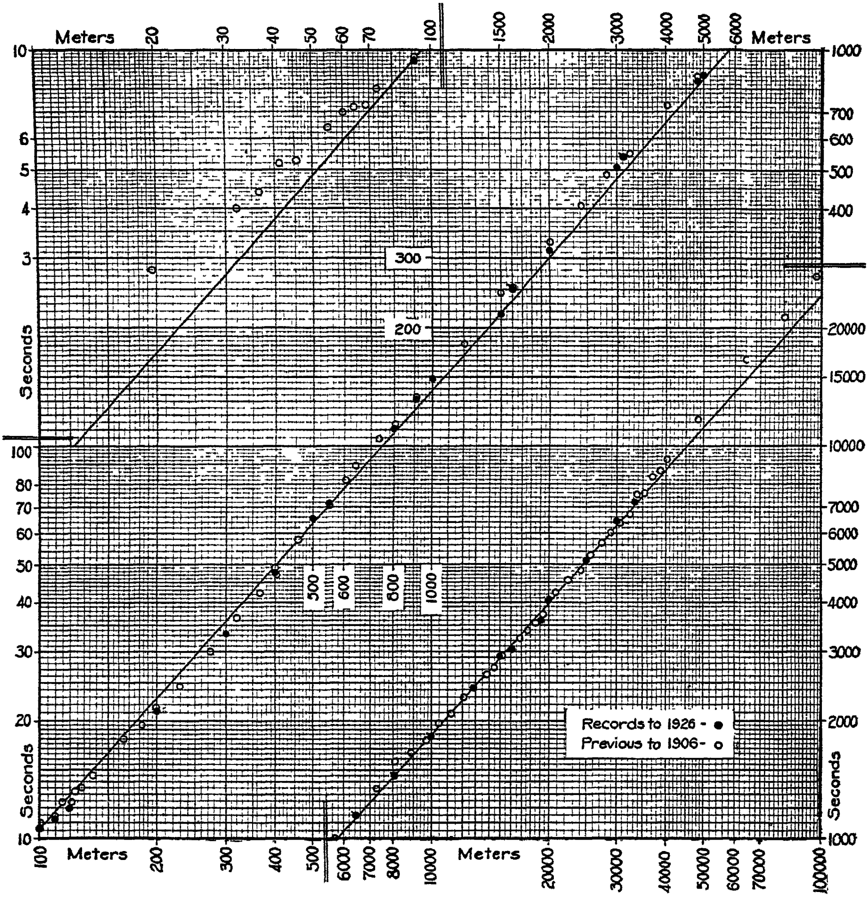
MEN RUNNING—RECORDS FROM 1906 TO 1926.

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
1910	100 yds.	9.4	91.4	9.727	0 9731	1 9611	0 9880	9.5	0 1
1921	100 m.	10.4	100	9 615	1 0170	2.000	0.9830	10.45	0 05
1909	120 yds.	11.25	109.7	9 752	1 0512	2 0403	0.9891	11.6	0 35
1911	130 yds.	12.0	118.9	9 906	1 0792	2 0751	0.9959	12 7	0.7
1921	200 m.	21.2	200	9 434	1.3263	2.3010	0.9747	22 8	1.6
1921	300 m.	33.2	300	9.037	1 5211	2 4771	0.9560	36 0	2.8
1924	400 m.	47.6	400	8.403	1 6776	2 6020	0.9244	49 7	2.1
1922	500 m.	65 5	500	7 635	1.8162	2 6990	0 8828	63 9	− 1.6
1910	600 yds.	70 8	548 6	7 750	1 8500	2 7393	0.8893	71.0	+ 0 2
1912	800 m.	111.9	800	7 150	2 0488	2.9031	0.8543	108.4	− 3.5
1916	880 yds.	112.2	804.7	7.171	2 0500	2 9056	0 8556	109 2	− 3.0
1921	1000 yds.	132.2	914.4	6 916	2 1212	2 9611	0 8399	126.0	− 6 2
1922	1000 m.	148.5	1000	6 734	2 1717	3 00	0.8283	139.4	− 9.1
1924	1500 m.	223.6	1500	6.708	2 3495	3 1761	0.8266	220.	− 3 6
1923	1 mi.	250.4	1609 3	6 427	2 3986	3 2066	0.8080	238 1	−12.3

TABLE IV.—*Continued.*

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
1922		326.3	2000	6.129	2.5136	3.3010	0 7874	304 1	− 22.2
1925		507.5	3000	5.911	2.7054	3.4771	0.7717	479.7	− 27.8
1925	2 mi.	538.2	3218.7	5.981	2.7309	3 5077	0.7768	519.4	− 18.8
1925	3 mi.	836.2	4828	5.774	2 9223	3 6838	0 7615	819.6	− 16.6
1925		863 2	5000	5.793	2.9361	3.6990	0 7629	852 3	− 10.9
1924	4 mi.	1148 7	6437	5 603	3 0657	3.8087	0 7430	1133	− 15 7
1924	5 mi.	1453 4	8047	5.536	3.1683	3 9056	0.7373	1456	+ 2.6
1924	6 mi.	1747 8	9656	5.525	3.2507	3.9848	0 7341	1787	+ 39 2
1924		1823 2	10000	5 485	3 2608	4 00	0 7392	1859	+ 35 7
1906	8 mi.	2416	12875	5 329	3.3831	4.1097	0 7266	2470	+ 54
1913		2838 6	15000	5 285	3.4531	4.1761	0 7230	2934	+ 95 4
1906	10 mi.	3040.6	16094	5.292	3.4830	4 2066	0 7236	3175	+134.4
1913		3600	19022	5.284	3.5563	4.2793	0.7230	3833	+233
1923		4031 2	20000	4.961	3.6054	4.3010	0 6956	4055	+ 23.8
1923		5120	25000	4.882	3.7093	4 3979	0 6886	5212	+ 92
1922		6433.3	30000	4.663	3.8084	4.4771	0.6687	6397	− 36
1911		7200	33057	4 592	3 8573	4.5193	0 6620	7137	− 73

FIGURE 4. WORLD'S RUNNING RECORDS



other running distances. Between 600 and 6,000 meters, the events are mostly above the line; although as we shall see presently, they have been brought down nearer to it in the last twenty years. Over this range then, the times are relatively long, and, in spite of recent successful attacks, the records seem more vulnerable, than below 600 meters.

In the bottom section, the events conform fairly well to the line from 6,000 to 40,000 meters. Beyond 40 km., the times are relatively

long, and the events plot high. This relative weakness of the very long runs may be due either to the view that they have not been sufficiently contested for by athletes, or that the law of fatigue, represented by the straight line, undergoes some modification beyond 40 km.

Taking Fig. 4 as a whole, it is evident that there has been no marked change in world's running speeds during the last twenty years. There have been a few records broken in the sprints between 90 and 200 meters, and these have raised the maximum racing speed averaged over a course, from 9.8 to 9.9 meters per second, at 120 meters distance. This is one of the notable running achievements of these two decades. There have also been a number of new world's records established particularly at metric distances, such as 2 km., 3 km., etc. This is merely an indication of the infiltration of the international metric system of weights and measures into American sports, through our contact with world events. In 1906, only a few metric events were reported in the "World Almanac." In the latest editions, there are about two-thirds as many metric as non-metric running records. At this rate of change, the mile and the yard are likely to become superseded units of athletic distance in the course of a few more decades. No other solution indeed seems ultimately possible, in order to bring athletics to a completely international basis. Some of the new metric records plot well above the line, and will probably be brought down in future contests, judging by older records near to them.

Noteworthy improvements in records have also been accomplished during the past twenty years within the fairly long-run range 600–9,000 meters. As was pointed out in the earlier paper, the records prior to 1906 were weak over this range, since they plotted well above the line. A number of improved records have since been made in this specially vulnerable range. The new ones plot nearer to the line, or in a few cases they actually reach the line. The celebrated recent exploits of Nurmi and Ritola have made inroads into this weak range of distances.

The straight lines of Fig. 4 are drawn to repeat the formula of the earlier paper: namely

$$T = \frac{L^{9/8}}{17.01} \qquad \text{seconds} \qquad (12)$$

and

$$V = \frac{17.01}{L^{1/8}} \qquad \text{meters per second} \qquad (13)$$

Men Walking

There have been relatively few changes reported in walking records since 1906. The records for five events have been improved (1, 2, 4, 7 and 8 miles). Six new metric distances have been added (3, 5, 10, 15, 20 and 25 km.). One new mile distance has been added (25 miles). Beyond that distance, no changes or additions appear to have been made. All the new records appear in Table V; while the full series of old and new records appear in Fig. 5.

Figure 5. WORLD'S WALKING RECORDS

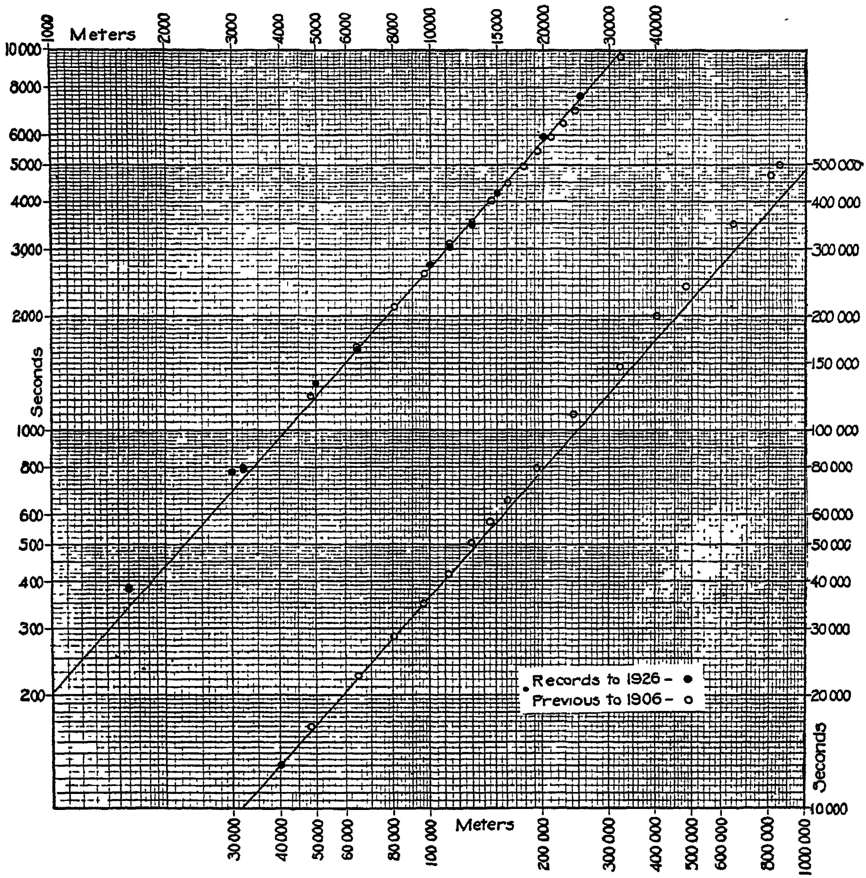


TABLE V.

MEN WALKING—RECORDS FROM 1906 TO 1926.

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
1913	1 mile	382	1609	4.212	2.5821	3.2066	0 6245	349	− 33
1918	3 km.	773.8	3000	3.877	2.8886	3.4771	0.5885	703.2	− 70.6
1904	2 miles	791.4	3219	4 068	2.8984	3.5077	0.6093	761.4	− 30
1918	5 km.	1319.8	5000	3.788	3.1205	3.6990	0.5785	1250	− 69 8
1905	4 miles	1634	6437	3.939	3.2133	3.8087	0.5954	1660	+ 26
1918	10 km.	2726.4	10000	3.667	3.4356	4 0000	0.5644	2725	− 1.4
1915	7 miles	3040.8	11265	3.705	3.4830	4.0517	0.5687	3116	+ 75.2
1905	8 miles	3498.4	12875	3.680	3.5439	4.1097	0 5658	3621	+122 6
1918	15 km.	4223	15000	3.552	3 6256	4 1761	0 5505	4300	+ 77
1918	20 km.	5962	20000	3.355	3.7754	4.3010	0.5256	5943	− 19
1919	25 km.	7624.3	25000	3.279	3 8822	4.3979	0 5157	7638	+ 13.7
1911	25 miles	13026.8	40235	3 089	4.1148	4.6047	0.4899	13053	+ 26

A peculiarity of walking records, to which attention was called in the earlier paper, is that all the records up to a distance of 6 km., lie above the line, or are affected by relatively low speed. This cannot be attributed to starting inertia, because the running races show that their inertia retardation practically disappears beyond distances of 100 meters, and with the lesser speeds of walking, the starting inertia retardation should be smaller still. It might possibly be accounted for by the limitations of the human mechanism, in relation to this particular mode of progression or gait. The man who keeps contact with the ground at all times, as in heel-and-toe walking, is perhaps prevented from advancing at the speed which brings him to the goal muscularly exhausted, when the distance to be covered is less than six kilometers.

Beyond 120 km. also, the points on the diagram move upwards from the straight line. It is uncertain whether the extra low speed of these long walking races is due to lack of competition, or to the intervention of some other and different law of fatigue. When the race lasts more than twelve hours, it is evident that other factors of retardation may come into play. Between the limits of 6 km. and 120 km., however, the events plot close to the straight line of the earlier paper. This straight line represents the relations:

$$T = \frac{L^{9/8}}{11.6} \qquad \text{seconds} \qquad (14)$$

and

$$V = \frac{11.6}{L^{1/8}} \qquad \frac{\text{meters}}{\text{second}} \qquad (15)$$

Men Rowing

Three new records are reported in eight-oar races (2, 3 and 4 miles), and one in four-oar races (2 miles). There does not seem to have been any marked change in the position of the lines which were drawn on the diagram of the earlier paper. The fluctuating influence of wind during the particular period of a boat race, makes the normal boat speed in the absence of wind, more difficult to determine. Table VI presents the new records, and Fig. 6 repeats the earlier diagram with the new records incorporated.

The best record of the Oxford-Cambridge University races has also been marked in Fig. 6 and Table VI, taking the distance as reported at 4¼ miles (6840 meters). This race is reported as having been rowed seventy times, over the Putney to Mortlake course, since

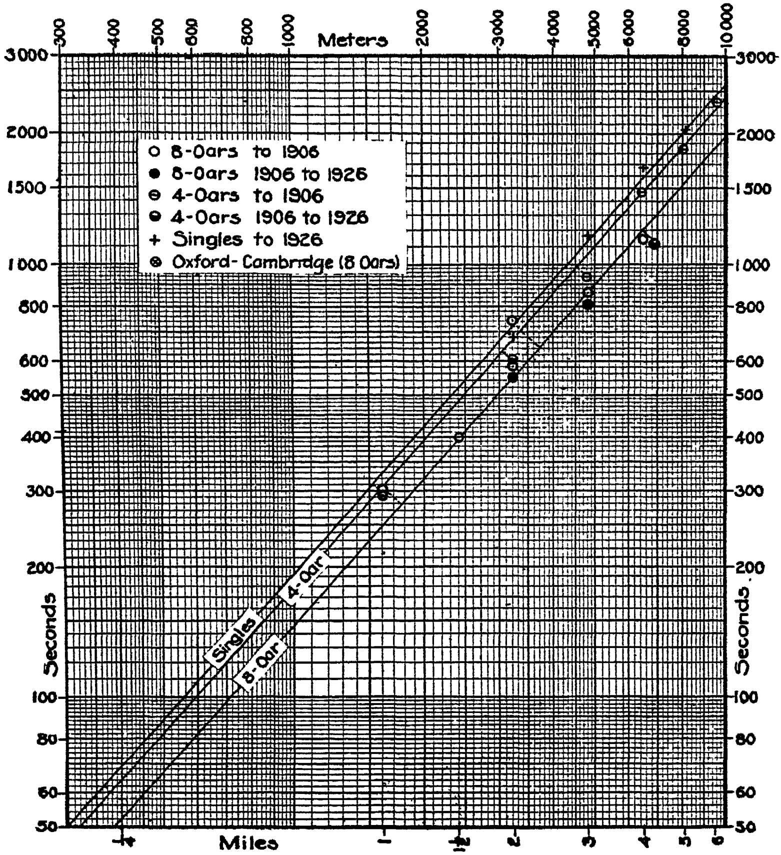
TABLE VI.

MEN ROWING—RECORDS FROM 1906 TO 1926.

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
	Eight Oars								
1909	2 mi.	547 6	3218 7	5 877	2.7385	3.5077	0 7692	554 9	+ 7 3
1922	3 mi.	813.6	4828	5.934	2 9104	3.6838	0 7734	875 6	+ 62 0
1901	4 mi.	1133.2	6437.4	5.680	3.0543	3.8087	0.7544	1210	+ 76 8
1911	4¼ mi.*	1109	6840	6.168	3.0449	3 8351	0 7902	1296	+187
	Four Oars								
1909	2 mi.	601	3218.7	5.355	2.7789	3 5077	0.7288	678 8	+ 77.8

* Oxford-Cambridge Boat Race, Putney to Mortlake, 4¼miles, lowest time in 70 years.

FIGURE 6. ROWING RECORDS



1845 inclusive. The mean racing time of all these events is 1286.7 seconds which is only 9.3 seconds short of the computed time for 6840 meters.

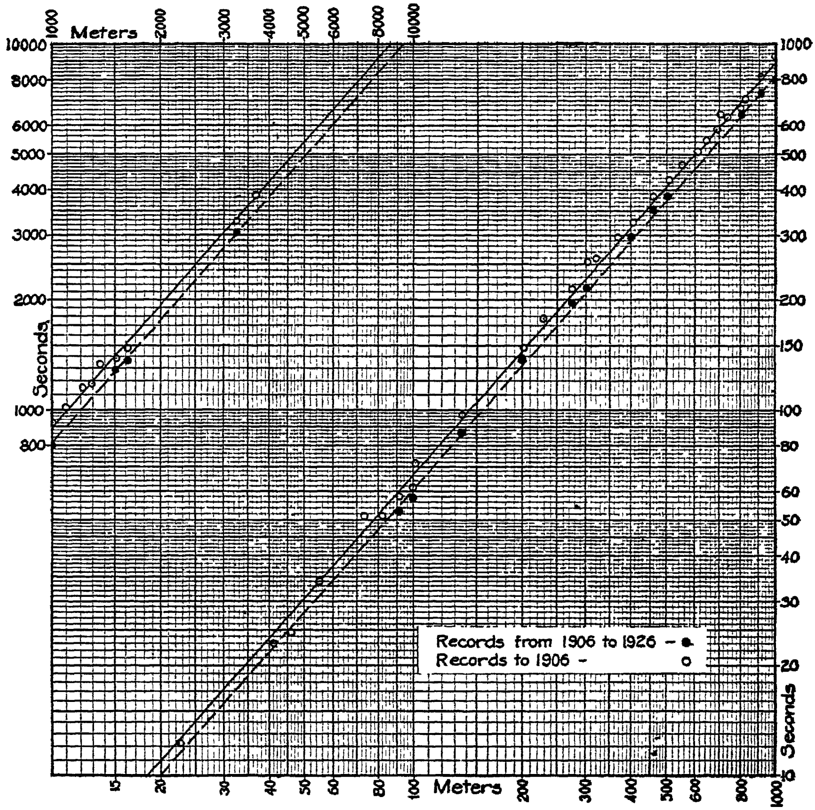
The three lines of Fig. 6 are drawn to correspond to the equations

8 oars	*4 oars*	*Singles*		
$T = \dfrac{L^{9/8}}{15.92}$	$T = \dfrac{L^{9/8}}{13.02}$	$T = \dfrac{L^{9/8}}{12.16}$	seconds	(16)
$V = \dfrac{15.92}{L^{1/8}}$	$V = \dfrac{13.02}{L^{1/8}}$	$V = \dfrac{12.16}{L^{1/8}}$	$\dfrac{\text{meters}}{\text{second}}$	(17)

MEN SWIMMING

A considerable number (16) of new swimming records have been reported during the past twenty years. They are presented in Table VII and plotted in Fig. 7.

FIGURE 7. WORLD'S SWIMMING RECORDS



It will be seen that the new records lie for the most part so far below the old line, that a new and broken parallel line has been drawn to represent them more closely. This corresponds to a distinct improvement in swimming speeds in the last two decades, and constitutes a noteworthy accession to human athletic accomplishment. The only other such improvement reported in this paper has already been noted,

TABLE VII.

MEN SWIMMING—RECORDS FROM 1906 TO 1926

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
1925	100 yds.	52.0	91.44	1.758	1.7160	1.9611	0.2451	55.7	3.7
1924	100 m.	57.8	100	1.730	1 7619	2.0000	0.2381	61.6	3.8
1925	150 yds.	86.4	137.2	1.588	1.9365	2.1372	0.2007	85.5	— 0 9
1922	200 m.	135 6	200	1.475	2.1323	2.3010	0.1687	134 4	— 1 2
1922	220 yds.	135.6	201.2	1.484	2 1323	2.3036	0.1713	135.3	— 0.3
1922	300 yds.	196 6	274.3	1.395	2 2936	2.4382	0.1446	191.7	— 4.9
1922	300 m.	215 2	300	1.394	2.3328	2.4771	0.1443	212.1	— 3.1
1923	400 m.	297.0	400	1.347	2.4728	2.6021	0.1293	293.2	— 3 8
1923	440 yds.	297.0	402.3	1.355	2.4728	2.6046	0.1318	295.1	— 1.9
1923	500 yds.	350.4	457 2	1.305	2 5446	2.6601	0.1155	340.7	— 9.7
1922	500 m.	384.2	500	1 301	2.5846	2.6990	0.1144	376.9	— 7.3
1924	880 yds.	657 8	804 6	1 223	2.8181	2.9056	0.0875	643.6	—14.2
1924	1000 yds.	736 9	914.4	1 241	2.8674	2.9611	0.0937	743.0	6.1
1924	1000 m.	799.6	1000	1 250	2.9029	3 000	0.0971	821.9	22.3
1924	1500 m.	1295.3	1500	1.158	3.1124	3.1761	0.0637	1297	1.7
1924	1 mi.	1354	1609 3	1.188	3.1316	3.2066	0.0750	1403	. 49.0
	2 mi.	3020.4	3219	1.066	3.4801	3.5076	0.0275	3061	40.6

in relation to the speeds of running horses which was relatively small increase of about 2 per cent, attributable presumably to improvement in the breeding of horses, as racing animals, by artificial selection. In this case of swimming men, however, the improvement is attributable to the invention and development of a new method of self-propulsion in the water, called "free style," as compared with the earlier style of racing. The improvement in swimming speeds thus attained, has amounted to very nearly ten per cent—a notable achievement.

The earlier records and their straight line follow the formulas:

$$T = \frac{L^{9/8}}{2.628} \qquad \text{seconds} \qquad (18)$$

and

$$V = \frac{2.628}{L^{1/8}} \qquad \frac{\text{meters}}{\text{second}} \qquad (19)$$

The broken straight line drawn for the new records follow the formulas

$$T = \frac{L^{9/8}}{2.885} \qquad \text{seconds} \qquad (20)$$

$$V = \frac{2.885}{L^{1/8}} \qquad \frac{\text{meters}}{\text{second}} \qquad (21)$$

Men Skating

There have been many new skating records since 1906; although it is doubtful if they show any general increase in speeds. Skating records are apt to be appreciably affected by wind velocities; so that a high degree of precision in their quantitative sequence is not to be expected. In the paper of 1906, analysis was confined to amateur skating records. Table VIII contains both amateur and professional records.

All the records are plotted in Fig. 8, which repeats the straight line obtained in the earlier papers. It will be observed that the times are relatively long, and average speeds low, for distances less than 400 meters. This is perhaps attributable to starting inertia. Beyond that distance, the events conform fairly well with the straight line up to 150 km. This straight line can be represented by

$$T = \frac{L^{9/8}}{25.96} \qquad \text{seconds} \qquad (22)$$

and

$$V = \frac{25.96}{L^{1/8}} \qquad \frac{\text{meters}}{\text{second}} \qquad (23)$$

TABLE VIII.

MEN SKATING—RECORDS FROM 1906 TO 1926

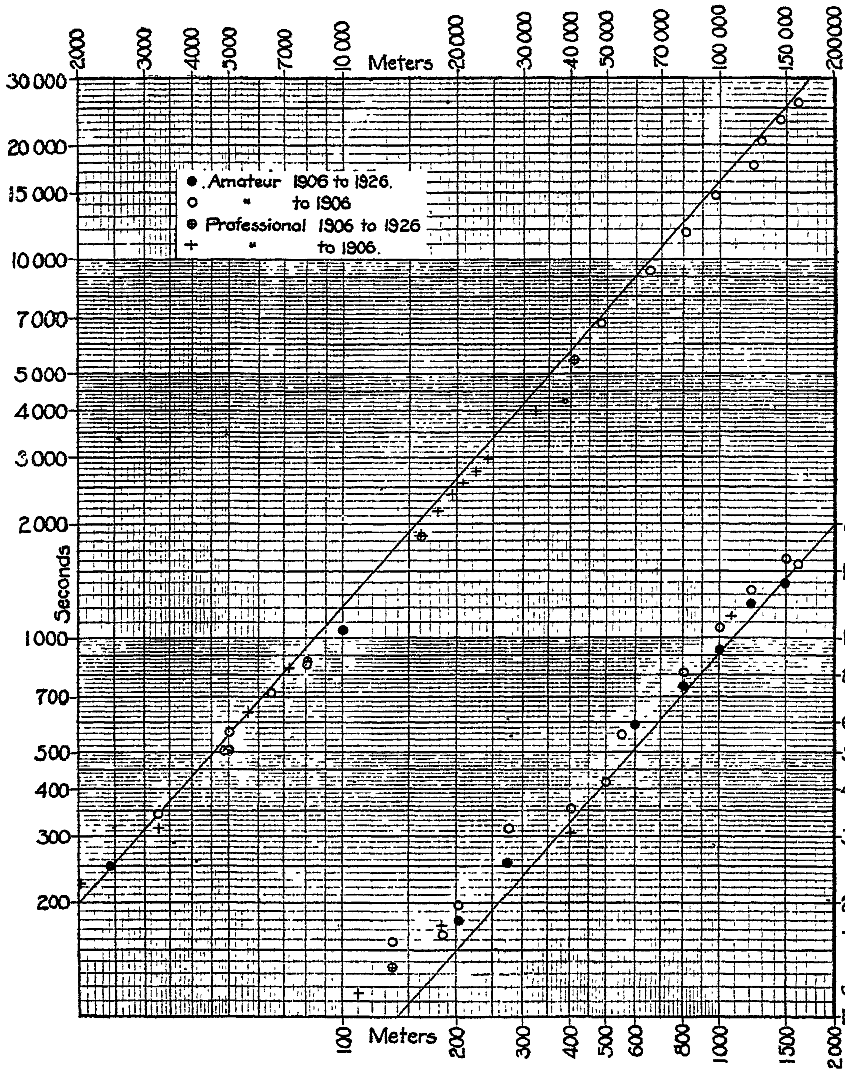
AMATEUR AND PROFESSIONAL

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
1914	50 yds.	5	45.72	9.144	0 6990	1.6601	0.9611	2.84	− 2.16
1905	75 "	8.2	68 58	8.363	0 9138	1 8362	0 9224	4 48	− 3.72
1923	100 "	8.8	91.44	10.39	0.9445	1.9611	1 0166	6.19	− 2.61
1893	120 "	11.6	109.67	9.458	1.0645	2 0403	0 9758	7.60	− 4 0
1923	150 "	13.6	137.2	10.090	1.1335	2.1372	1.0037	9.78	− 3.82
1894	220 "	17 8	201.2	11.30	1.2504	2.3026	1.0522	15 04	− 2.76
1916	300 "	25.4	274.3	10.80	1.4048	2.4382	1.0334	21 32	− 4.08
1904	660 "	59.6	603.6	10.13	1.7752	2.7807	1 0055	51.8	− 7.8
1918	880 "	75.0	804.6	10.60	1.8753	2.9056	1.0303	71.5	− 3.50
1910	1 km.	91.8	1000	10 89	1.9628	3 0000	1.0372	91 4	− 0.4
1895	1173 yds.	114.8	1072.9	9.347	2.0599	3.0306	0.9707	98.9	−15.9
1923	1320 "	122.2	1207.0	9.878	2.0864	3 0817	0.9953	112.9	− 9.3
1914	1500 m.	139.5	1500	10 75	2.1446	3.1761	1.0315	144.1	+ 4.6
1916	1 mi.	155.0	1609.3	10.38	2 1903	3.2066	1.0163	156.0	+ 1
1910	1.5 mi.	250.0	2414	9.656	2.3979	3.3837	0 9858	246.8	− 3.2

TABLE VIII.—*Continued.*

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V	log T	log L	log V	T′ Computed Secs.	T′—T Deviation Secs.
1900	2 mi.	333 8	3218.7	9.642	2.5235	3.5077	0 9842	340 3	+ 6.5
1923	3 "	501.4	4828	9 628	2.7002	3 6838	0 9836	537 1	+ 35 7
1922	5 km.	506.5	5000	9.872	2.7046	3.6989	0 9943	558 5	+ 52 0
1922	5 mi.	855	8046.7	9.413	2.9320	3.9056	0 9736	951	+ 99
1913	10 km.	1042.6	10000	9 590	3.0181	4 000	0.9819	1218	+175 4
1919	10 mi.	1867.5	16093	8.618	3.2613	4.2066	0 9453	2080	+212.5
	11 "	2143.8	17702	8.258	3.3312	4.2480	0 9168	2316	+172.2
	12 "	2329.8	19310	8.288	3.3673	4.2858	0.9185	2554	+224.2
	13 "	2547.4	20919	8.212	3.4061	4.3206	0 9145	2795	+247 6
	14 "	2751.8	22529	8.188	3.4396	4.3528	0 9132	3038	+286.2
	15 "	2957.6	24140	8.162	3.4709	4.3827	0.9118	3282	+324.4
	20 "	3996.4	32186	8.055	3.6017	4.5077	0.9060	4538	+541.6
1916	25 "	5415	40233	7.431	3.7336	4.6047	0 8811	5834	+419

FIGURE 8. WORLD'S SKATING RECORDS



MEN BICYCLING

In the earlier paper, the records available were pointed out as being inconsistent and incomplete. The records, when plotted, indicated a

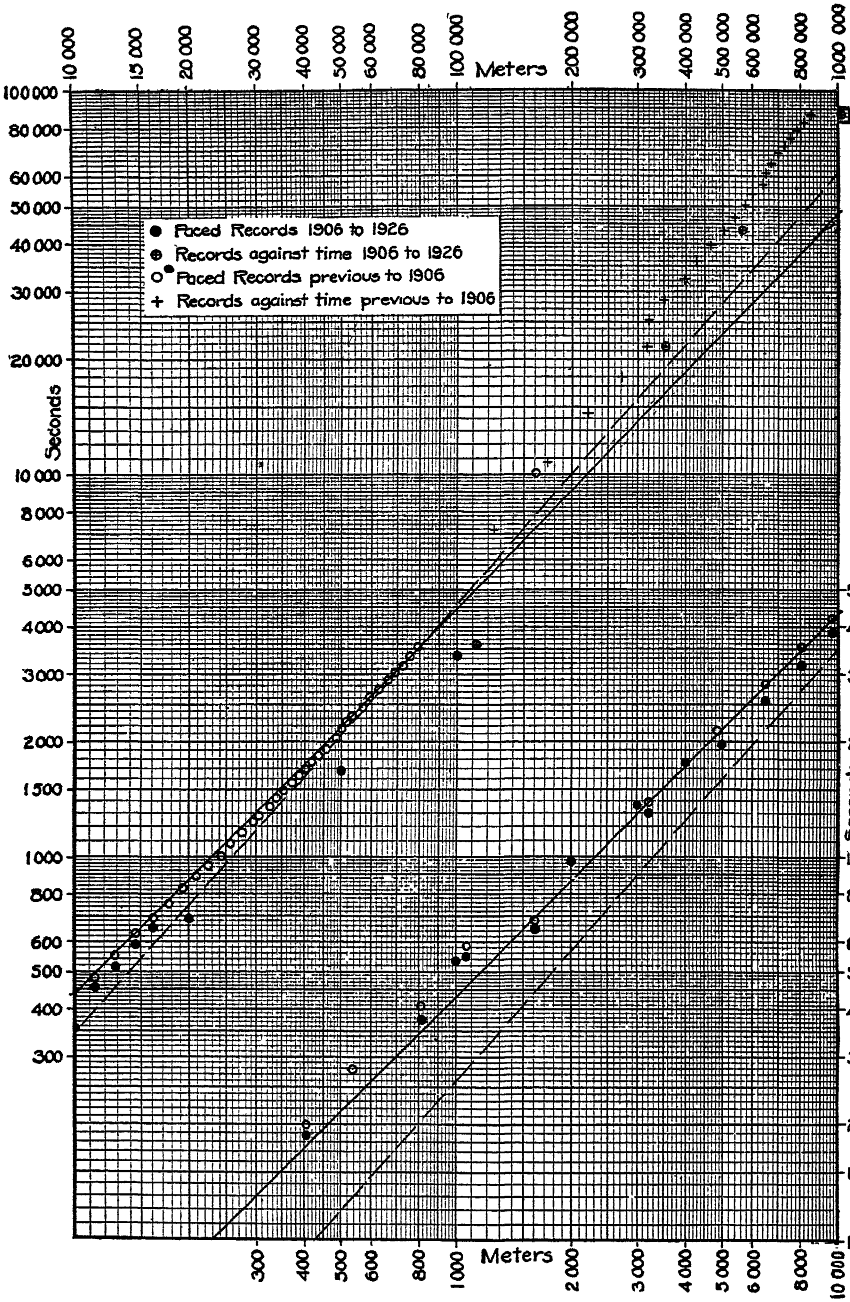
nearly uniform racing speed over all courses up to about 50 km., disregarding the very short races; so that there was apparently no indicated fatigue until after that distance had been covered. Beyond 50 km., the speeds fell off with further increase in distance, but somewhat irregularly. The new records are also inconsistent. Some of them were made with special wind shields supported on the pacing motor. These belong to a class by themselves, the speeds attainable in that way, being considerably greater. The new records appear in Table IX and Fig. 9 gives the diagram of all the records. The broken

TABLE IX.

MEN BICYCLING—RECORDS FROM 1906 TO 1926.

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V
1913	¼ mi.	18.8	402 3	21.40
1913	½ mi.	37.6	804 6	21.40
	1 km.	53 6	1000	18.66
1910	⅔ mi.	55 0	107.28	19.50
1917	1 mi.	64 2	1609.3	25.07
	2 km.	97 2	2000	20.58
1909	2 mi.	129 8	3218.7	24.79
	3 km.	137	3000	21.90
	4 km.	176	4000	22.73
1917	3 mi.	193.4	4828	24.96
	5 km.	194.2	5000	25.75
1917	4 mi.	256.8	6437.4	25.07
1917	5 mi.	318 4	8046.7	25.27
1909	6 mi.	388.2	9656	24.87
	10 km.	356.4	10000	28.06
1909	7 mi.	453.6	11265	24 84
1909	8 mi.	518.2	12875	24.85
1909	9 mi.	585.8	14484	24.73
1917	10 mi.	659 6	16093	24.40
	20 km.	686 6	20000	29.13
	50 km.	1687.4	50000	29.64
	100 km.	3335.8	100000	29.98
	69 mi. 1526 yd.	3600	112445	31.24
1902	220 mi. 1410 yd.	21600	355350	16.45
1899	349 mi. 1447 yd.	43200	563020	13 03
1899	634 mi. 774 yd.	86400	1021100	11.82

FIGURE 9 BICYCLING RECORDS



straight line is drawn at the same angle of 48° 22′ with the base, as in the preceding Figures. It can only be regarded as conforming very imperfectly with the records on the longer races. The actual speeds as shown in Fig. 11, are not far from uniform at 23 meters per second up to 100 km. distance. The highest course speed recorded is actually 31.24 meters per second developed in a wind-shielded run of 112.4 km. Until bicycle contests are more standardized, there seems to be little hope of consistent record behavior. The heavy straight line in Fig. 9 is drawn at an angle of 45° with the axes, to correspond to the uniform racing speed of 23 meters per second, or performance without the appearance of fatigue.

Automobiles

At the date of the earlier paper, the records made by automobiles over varying distances had not been sufficiently well established to warrant presentation. The automobile, being propelled by inanimate mechanism and not by muscles, is exempt from fatigue in the ordinary sense. We should therefore expect that, except for starting inertia, which would prevent the development of full speed over short runs, an automobile of a given make, should be able to run at constant full speed over any standard uniform course of any length. When, however, very long distances have to be run in the contest, we might expect occasional accidental delays to occur, either from nervous fatigue on the part of the driver, or from the effect of impaired mechanism, reduced lubrication or the like. This is in agreement with the records, which are presented in Table X and Fig. 10.

Referring to Fig. 10, there are two parallel straight lines running side by side in two traverses across the sheet, the upper one broken and carrying open circles, the lower one unbroken, and with black circles. The former was drawn late in the year 1925, from records reported up to January 1st of that year. The latter has since had to be drawn, to cover the new records reported up to January 1st, 1926. Both lines make 45° with the axes, and therefore, correspond to uniform speed. The upper line of 1925, corresponds to a speed of approximately 54.5 meters per second. The lower line of 1926, to a speed of 60 meters per second. This shows that over the range between 8 km. and say 100 km., a speed increase of about 10 per cent. has been effected in the year 1925 alone. Both lines and sets of records have been presented for automobiles, as a matter of interest. The corresponding two horizontal lines of constant speed appear in Fig. 11.

TABLE X.

RECORD OF AUTOMOBILES—SPEEDWAY RECORDS COMPETITIVE.

Date	Distance	Time Seconds T	Distance Meters L	Mean Speed m/sec. V
1916	1 mi.	40.23	1,609.3	40.00
1917	2 "	69.57	3,218.6	46.26
1916	3 "	114.81	4,828	42.05
1917	4 "	134.22	6,437	47.96
1925	5 "	134.60	8,046.7	59.78
1925	10 "	265.20	16,094	60.67
1925	15 "	395.60	24,140	51.02
1925	20 "	530 40	32,190	60.68
1925	25 "	666 60	40,240	60.36
1925	50 "	1,331.00	80,470	60.35
1925	75 "	2,100 48	120,700	57.46
1925	100 "	2,801 39	160,930	57.44
1925	150 "	4,243.60	241,400	56 89
1924	200 "	5,680.80	321,860	56.66
1925	250 "	7,093 60	402,400	56.73
1922	300 "	10,012.96	482,800	48.22
1915	350 "	12,282 99	563,330	45.86
1925	400 "	14,190 19	643,720	45.36
1925	450 "	16,080.10	724,210	45.04
1925	500 "	17,799.46	804,700	45.21

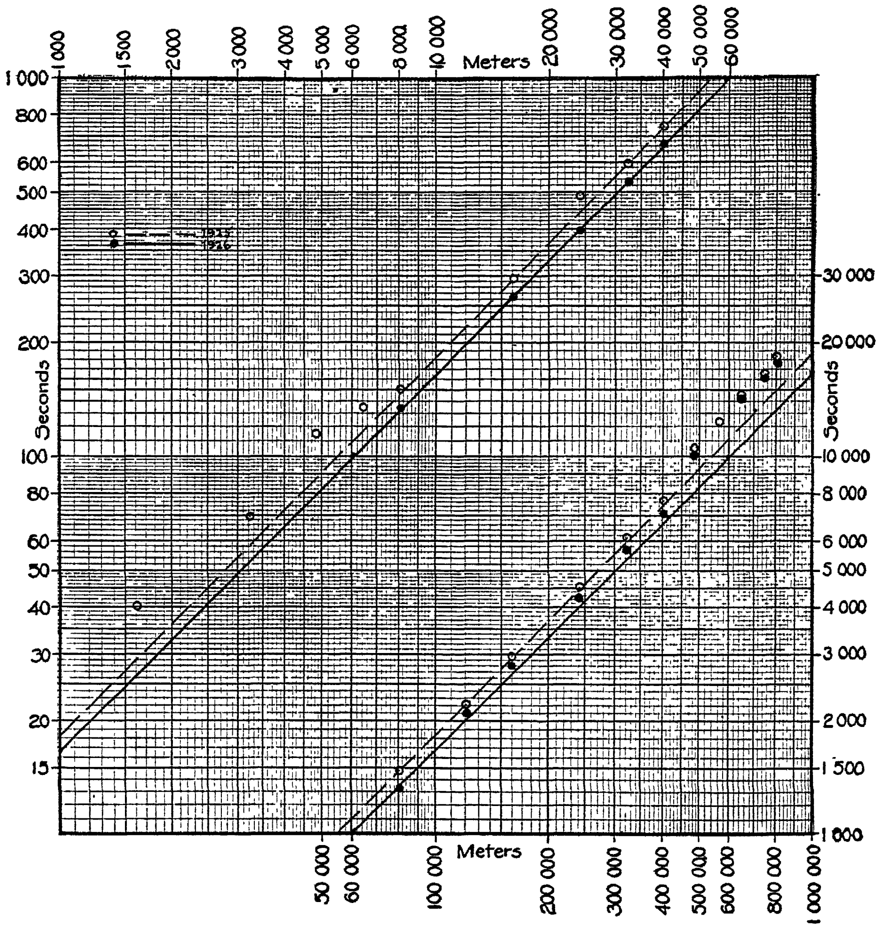
For runs of less than 8 km. the speeds appear defective, and again beyond 200 km.

It would not be necessary to use logarithm paper in dealing with these automobile records, in order to produce a straight-line relation, when plotting time against distance between 80 and 400 km. Ordinary uniformly squared paper would serve, since the velocities are substantially uniform over that range, and no "fatigue" is exhibited. A quasi fatigue is, however, exhibited between 500 and 800 km.

SPEED DISTANCE DIAGRAM

All of the diagrams 1 to 10 are, as already explained, time-distance diagrams on logarithmically ruled paper. Fig. 11 collects all the speed records for the various classes of events, according to formulas 3, 5, 7, etc. The ordinates are the mean speed over the course in

FIGURE 10. AUTOMOBILE RECORDS TO 1926



meters per second, and the abscissas, meters length of course. The diagram is logarithmically ruled. The lines are parallel, and are drawn to make an angle of 7° 7′ 30″ with the axis of abscissas, an angle whose tangent is —1/8. Two lines, however, are drawn horizontally, namely, (1) the automobile line pair, at constant speeds of 54.5 and 60 meters per second, and (2) the bicycle line, at a constant speed of 23 meters per second. We have already seen that fatigue is manifested in the longer bicycle runs, although not, at this date, in a consistent manner.

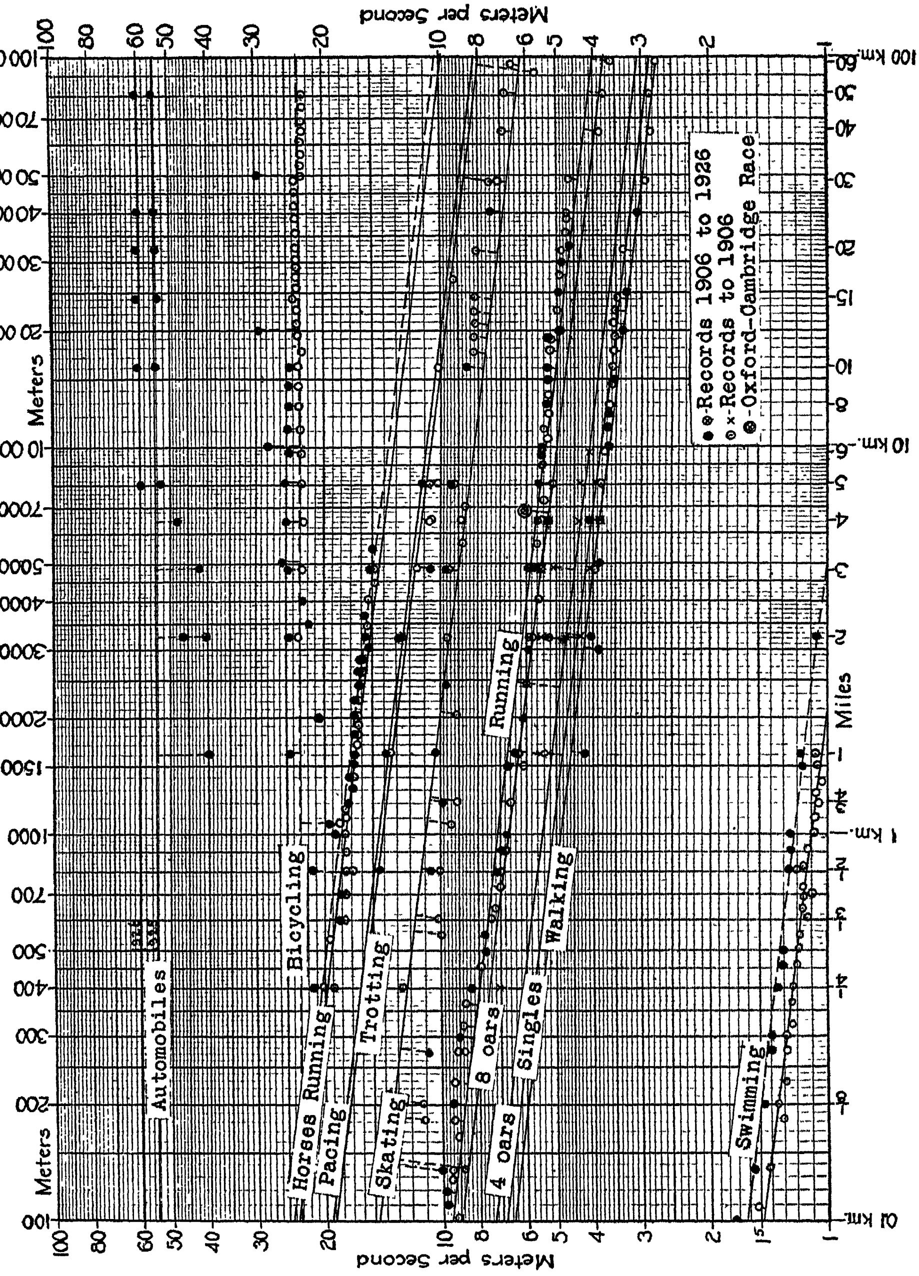


FIGURE 11. SPEED-DISTANCE LINES

TABLE XI.

Speeds over Courses at 1-Kilometer and 1-Mile Distances.

I	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.
Table.	Racers.	log c.	c.	Speed at 1 Kilometer.		Computed Time for 1 Kilo-meter, seconds.	Record Time for 1 kilo-meter seconds.	Speed at 1 km.	Speed at 1 Mile.			Com-puted Time for 1 Mile, seconds.	Record Time for 1 Mile, seconds.
				log.	meters / seconds			km. / hours.	log.	meters / seconds.	miles / hours.		
X	Automobiles 1925	—	—	—	54.5	18 34		196.2	—	54.5	121.9	29.5	40 23
	" 1926	—	—	—	60.0	16 67		216.0	—	60.0	134.2	20.8	"
IX	Bicycles	—	—	—	23 0	43.48	53.6	82.8	—	23.0	51.45	70.0	64.2
	Horses running 1906	1 6274	42.4	1.2524	17 88	55 9		64.4	1.2266	16.85	37.70	95.5	95 5
II	" " 1926	1.6375	43.4	1.2625	18 30	54.6		65.9	1 2367	17.25	38.58	93.30	95.4
III	Horses pacing	1.5363	34.38	1 1613	14.50	68.98		52.2	1 1355	13.66	30.56	117.8	115 25
I	Horses trotting	1.5302	33.9	1.1550	14.29	70.0		51.5	1.129	13.46	30.13	119 5	116.75
VIII	Men skating	1.4143	25.96	1.0393	10.95	91.35	91.8	39.4	1 0135	10.31	23.08	156.0	155.0
IV	Men running	1 2307	17 01	0 8557	7.173	139.4	148.5	25.8	0.8299	6.759	15 12	238.1	250.4
VI	Men 8-oars } rowing	1.2019	15.92	0.8270	6.714	148.9		24.2	0.8012	6 327	14 15	254.3	304.75
VI	Men 4-oars } rowing	1.1145	13.02	0 7395	5 489	182.2		19.8	0.7137	5.173	11 57	311.1	291.0
VI	Men singles } rowing	1.0849	12.16	0.7100	5.129	195.0		18.5	0.6842	4.833	10 81	333.0	301.0
V	Men walking	1.0646	11.6	0 6896	4 893	204.4		17.6	0.6638	4 611	10 32	349 0	382.0
VII	Men swimming 1906	0.4196	2.628	0 0446	1.108	902.4		4.0	0.0188	1 044	2.336	1544 0	1476.2
	" " 1926	0.4602	2.885	0.0852	1.217	821.9	799.6	4.4	0.0594	1.147	2 565	1403 5	1354

Table XI collects the results of the different classes of events in regard to speed. It corresponds to Table XVIII of the earlier paper.

It will be seen that over a course of 1 kilometer, the racing speed varies from 17.88 m./sec. or 64.4 km./hr. with running horses, to 1.217 m./sec. or 4.4. km./hr. for swimming men. The time required to make the kilometer, ranges similarly in these two classes of events from 55.9 seconds to 821.9.

The tables and diagrams here presented, together with those of the earlier paper, show that, within a moderate degree of precision, the relations between time, distance and average speed, are those of equations (1), (2) and (3). The question naturally presents itself as to what bearing those relations have upon the best method of controlling speed in running a race, in order to make a record. For the mens' running races, up to distances of say 400 meters, no suggestions offer themselves, because the time occupied in running is well below one minute, and the runner must sprint at full speed all the time. This is the practice that has long been recommended for sprinters, in books on training for the running track. When, however, the distance to be run exceeds 400 meters, and particularly, when it covers many kilometers, the suggestion presenting itself from this analysis, is that the speed of the runner should be as nearly uniform as possible, throughout the race, and that both spurts and relaxations are detri, mental to best performance. As was pointed out in the 1906 paper- this is because the penalty for high speed is so great in all the events. A record-making runner averages 7.7 meters per second over a half. kilometer race; but only 6.7 meters per second over a 2-km. race- These statements give no particulars as to what the speeds of the record-maker may have been in different parts of the race, and events of different distances are ordinarily competed for by different athletes. Nevertheless, there are some athletes that have made records over a considerable range of distances. For example, Nurmi is credited with running records for various events from 1500 to 10,000 meters, with respective average speeds of 6.7 and 5.5 m. per sec. It is evident that he could not have kept up in any 1500 meters of his 10,000-meter race, the speed at which he made the 1500-meter record. His speeds over the different quarters of his mile race are also reported to have been nearly uniform,[1] and correspond to speeds of 6.87, 6.37, 6.20 and 6.33 meters per second. The deduction that long runs should be executed at as nearly constant speed as possible,[2]

[1] Bibliography 13.

[2] Bibliography 4, 11.

does not seem to be in conformity with the recommendations of books on track training, with a few exceptions of recent date.[3] The customary advice is to commence a mile race at a speed well in excess of the average, for a few seconds, in order to secure headway and free space among the contestants, then to run the first quarter distinctly in excess of the average, the second quarter nearer to the average, the third below the average, and the final quarter with a spurt at the highest available speed. There can be no doubt as to the propriety of running the last section of the race as fast as possible, on any theory of action; but it is questionable, in the light of this analysis, how much departure from and above the average should be allowed in the earlier sections. The law of distances and times versus average speed from (1) is that one per cent increase in speed reduces the running distance about eight per cent, and the running time to exhaustion about nine per cent. This is a heavy penalty for overspeeding.

If this reasoning is correct, it would seem desirable that, in the training of long-distance runners, a phosphor-bronze wire should be run alongside the track over guide pulleys, being driven by a small electric motor housed at some convenient position on the route. The speed of the wire could be controlled by an observer in the house, furnished with an electrically driven stroboscopic[4] fork, and could be maintained constant, with all desired precision, at the suitably reduced average speed for the event under consideration. A small flag could be temporarily attached to the wire as a pacing signal, and the athlete's task would be to keep abreast of it.

The question presents itself why the relations between time, distance and average speed, in the various classes of events here considered, should follow the particular exponents given in formulas (1), (2) and (3). No answer is as yet forthcoming. It is essentially connected with the physiology of muscular activity. The researches of Prof. A. V. Hill[5] and his associates, have however opened upon the question. They have shown that when athletic exercise begins, the oxygen intake rises suddenly from a low value, characteristic of rest, to a high value, characteristic of the effort undertaken. The oxygen requirement is proportional to the total muscular work done. The available inhalation rate of supply is limited. The body can, however, go into debt for oxygen, or incur an oxygen deficit, up to a certain limit. When this oxygen debt amounts to about 15 liters, at ordinary

[3] Bibliography 13.
[4] Bibliography 5.
[5] Bibliography 12.

atmospheric pressure, the body becomes incapable of further muscular effort and becomes temporarily exhausted. Each liter of oxygen absorbed by inhalation and consumed in the active body, liberates about 5 kilogram-calories of energy which, if completely converted into mechanical energy, would be 2135 kilogram-meters. The muscular activity in a race can be varied at the will of the racer. He can inhale oxygen at any required rate up to about 4 liters per minute, but must arrive at the goal with a total deficit not exceeding 15 liters. The reader is referred to Hill's papers for further particulars on this very interesting and important subject. Until the quantitative physiological relations are further developed, we have to be content with the statistical facts.

Prof. A. V. Hill has also arrived at the same conclusion, as to uniform speed being the optimum speed, from physiological considerations.[6]

Conclusions

1. During the past twenty years, there have been two classes of racing events in which a general improvement in speeds can be detected; namely, men swimming, with a ten per cent increase, and horses running, with about two per cent increase. In the other classes of events, there have been individual improved records; but no general improvement in speed is clearly discernible.

2. Automobile records, during the past twenty years, indicate substantially constant speeds over all courses from 80 to 400 km., with some quasi fatigue between 400 and 800 km.

3. Bicycling records are not yet sufficiently developed and standardized to give consistent quantitative relations of speed versus distance.

4. Races over metric distances are today much more common than they were twenty years ago. At that time, world records were mostly over mile and yard distances.

5. Racing horses have continued to show a higher degree of professional precision in their performances, than racing men. That is, the average percentage deviation of observed times from computed times, over their series of events, is less than that of men. The plotted points for horse races conform more nearly to the straight line, than for men's races.

6. World's records in three classes of events for horses, and five classes of events for men, represent substantially the same law of

[6] Bibliography 11 and 12.

fatigue; namely that the time varies as the nine-eighths power of the distance, or as the inverse ninth power of the average speed; so that doubled racing speed corresponds to cutting down the running time to approximately one five-hundredth part (1/512).

7. Those records which lie above the straight lines of Figs. 1 to 8, are presumably more vulnerable and more easy to supersede, than those which lie below. The general result of the improvements in records during the past twenty years has been on the whole to bring the points nearer to the lines.

8. The indications are that the best schedule of speed control in any long race, i.e. any race that lasts say longer than one minute, is to maintain the speed as nearly uniform as possible throughout.

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Proceedings of the American Academy of Arts and Sciences.

VOL. 61. No. 12.—NOVEMBER, 1926.

RECORDS OF MEETINGS, 1925–26.

BIOGRAPHICAL NOTICES.

OFFICERS AND COMMITTEES FOR 1926–27.

LIST OF THE FELLOWS AND FOREIGN HONORARY MEMBERS.

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RUMFORD PREMIUM.

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RECORDS OF MEETINGS.

One thousand one hundred and forty-first meeting.

OCTOBER 14, 1925.—STATED MEETING.

The Academy met at its House at 8.15 P.M.

The PRESIDENT in the Chair.

There were present sixty-three Fellows and Associates and twelve guests.

The Records of the Annual Meeting, of May 13, were read and approved.

The following letters were presented by the Corresponding Secretary: from Nathaniel Allison, N. L. Britton, Vannevar Bush, S. R. Detwiler, H. M. Evans, W. C. Greene, A. S. Hitchcock, E. S. Larsen, Jr., W. J. Luyten, K. F. Mather, R. B. Osgood, A. G. Ruthven, F. B. Taylor, Benjamin White, and A. N. Whitehead, accepting Fellowship; from K. F. Geldner, John Horne, and Maurice d'Ocagne, accepting Foreign Honorary Membership; from C. F. Adams, C. F. Batchelder, H. W. Cunningham, William James, Everett Morss, C. H. Taylor, and B. L. Young, accepting Associate Fellowship; from Charles Hopkinson, declining Associate Fellowship; and from Arthur Foote, resigning Fellowship.

The Corresponding Secretary reported the receipt of biographical notices of Alfred Marshall, by F. W. Taussig; and of James Jackson Putnam, by A. C. Lane.

The President announced the deaths of seven Fellows:—George Burton Adams (Class III, Section 3), John Mason Clarke (Class II, Section 1), Leslie Colby Cornish (Class III, Section 1), William Curtis Farabee (Class III, Section 2), Isaac Minis Hays (Class III, Section 3), Albert Andrew Howard (Class III, Section 2), and Jay Backus Woodworth (Class II, Section 1); and of two Foreign Honorary Members:—Felix Klein (Class I, Section 1), and Heinrich Müller-Breslau (Class I, Section 4).

The newly elected Fellows and Associates were then presented.

At the request of the President, the Chairman of the Rumford Committee made a statement regarding the Rumford Fund and the

recipient of the Rumford medal, Professor Henry Norris Russell, of Princeton, to whom the President made the presentation of the medal.

The following communication was presented:

Mr. Henry Norris Russell: "The Present State of Theories of Stellar Evolution."

Six papers were presented by title:

"A Revision of the Atomic Weight of Germanium. II. The Analysis of Germanium Tetrabromide," by G. P. Baxter and W. C. Cooper, Jr. Presented by G. P. Baxter.

"The Latent Heat of Vaporization of Liquid Oxygen-Nitrogen Mixtures," by Leo I. Dana. Presented by H. N. Davis.

"Piezoelectric Crystal Oscillators applied to the Precision Measurement of the Velocity of Sound in Air and CO_2 at High Frequencies," by G. W. Pierce.

"A Mathematical Study of Crystal Symmetry," by A. F. Rogers.

"The Effect of Pressure on the Viscosity of Forty-three Liquids," by P. W. Bridgman.

"Thermal Conductivity and Thermal Electro-Motive Force of Single Crystals of Several Non-Cubic Metals," by P. W. Bridgman.

The Meeting was dissolved at 10.10 P.M.

One thousand one hundred and forty-second meeting.

NOVEMBER 11, 1925.—STATED MEETING.

The Academy met at its House at 8.15 P.M.

The PRESIDENT in the Chair.

There were present fifty-three Fellows and Associates and twenty guests.

The Records of the Meeting of October 14 were read and approved.

The Recording Secretary read portions of a letter from the Executive Secretary of the American Council of Learned Societies, announcing that through the generosity of the Laura Spelman Rockefeller Memorial Fund it will receive an annual subvention of $5,000 for the next three years, from which it will be able to make small grants in aid of individual projects of research in the humanistic and social sciences.

The President announced the death of Edward Stevens Sheldon, Fellow in Class III, Section 2.

The following communication was presented:

Professor Wolfgang Köhler, of the University of Berlin: "The Creative Side of Mental Life," illustrated with moving pictures.

One paper was presented by title:

"The Calendar of Ancient Israel," by W. A. Heidel.

The Meeting was dissolved at 9.40 P.M.

One thousand one hundred and forty-third meeting.

December 9, 1925.—Stated Meeting.

The Academy met at its House at 8.15 P.M.

The President in the Chair.

There were present thirty-eight Fellows and three guests.

The Records of the Meeting of November 11 were read and approved.

The Corresponding Secretary read portions of a letter from Professor Henderson concerning a project for depositing three notable collections of books on the History of Science in the Harvard College Library.

On recommendation of the Council, it was

Voted, That the Academy approves the depositing of its own books with these collections in the Harvard College Library, excepting proceedings of learned societies and serial publications published before 1800.

The following communication was presented:

Mr. Thomas Barbour: "Two New Tropical Biological Stations," illustrated with lantern slides.

The Meeting was dissolved at 9.30 P.M.

One thousand one hundred and forty-fourth meeting.

January 13, 1926.—Stated Meeting.

The Academy met at its House at 8.15 P.M.

The President in the Chair.

There were present thirty Fellows and three guests.

The Records of the Meeting of December 9 were read and approved.

The Corresponding Secretary reported the receipt of a biographical notice of Gustaf Magnus Retzius, by G. H. Parker.

The Corresponding Secretary announced that the Council would present some amendments to the Statutes to be voted on at the next meeting of the Academy.

The President announced the deaths of two Fellows:—William Otis Crosby (Class II, Section 1), and Edward Sylvester Morse (Class II, Section 3).

The following communication was presented:

Mr. William A. Heidel: "Calendars of Ancient Israel."

One paper was read by title:

"Changes during the Last Twenty Years in the World's Speed Records of Racing Animals," by A. E. Kennelly.

The Meeting was dissolved at 9.30 P.M.

One thousand one hundred and forty-fifth meeting.

FEBRUARY 10, 1926.—STATED MEETING.

The Academy met at its House at 8.15 P.M.

The PRESIDENT in the Chair.

There were present eleven Fellows.

In the absence of a quorum, the President declared that no meeting could be held.

One thousand one hundred and forty-fifth meeting.

MARCH 10, 1926.—STATED MEETING.

The Academy met at its House at 8.15 P.M.

The PRESIDENT in the Chair.

There were present fifty-five Fellows and Associates and twenty-five guests.

The Records of the Meetings of January 13 and February 10 were read and approved.

On recommendation of the Council, the following appropriations were made for the ensuing year:

From the income of the General Fund, $7,550, to be used as follows:

for General and Meeting expenses	$ 800.00
for Library expenses	1,800.00
for Books, Periodicals and Binding	1,200.00
for House expenses	2,650.00
for Treasurer's expenses	1,100.00

From the income of the Publication Fund, $3,133.41, to be used for publication.

From the income of the Rumford Fund, $3,503.12, to be used as follows:

for Research	$1,000.00
for Books, Periodicals and Binding	200.00
for Publication	600.00
for use at the discretion of the Committee	1,703.12

From the income of the C. M. Warren Fund, $1,050, to be used at the discretion of the Committee.

The following amendment to the Statutes was adopted by ballot:

Chapter IV

Article 1, Paragraph 1. The officers of the Academy shall be a President (who shall be Chairman of the Council), three Vice-Presidents (one from each Class), a Corresponding Secretary (who shall be Secretary of the Council), a Recording Secretary, a Treasurer, a Librarian, and an Editor, all of whom shall be elected by ballot at the Annual Meeting, and shall hold their respective offices for one year, and until others are duly chosen and installed.

Chapter VI

Article 3. The Secretaries, with the Editor, shall have authority to publish such of the records of the meetings of the Academy as may seem to them likely to promote its interests.

Chapter IX (New)

The Editor and the Publications

Article 1. The Editor shall have charge of the conduct through the

press of the Proceedings and the Memoirs, and all correspondence relative thereto, and shall have power to fix the price at which individual numbers of the Proceedings and the Memoirs are sold.

Article 2. In conjunction with the Committee of Publication, he shall have authority to expend such sums as may be appropriated by the Academy for printing the publications and for defraying other expenses therewith connected.

Article 3. All publications which are financed in whole or in part from the income of the Rumford Fund or from the income of other special funds, and all publications of work done with the aid of the Rumford Fund or other special funds, shall contain a conspicuous statement of this fact.

Article 4. Two hundred extra copies of each paper printed in the Proceedings or Memoirs shall be placed at the disposal of the author without charge.

If, on account of the number of communications offered for publication, it shall be necessary to decline for publication communications otherwise acceptable, members of the Academy shall be given preference in each of the several Classes over non-members; but whenever it shall be necessary to exercise this preference, the Editor shall inform the Council of the fact.

(Advance the chapter numbers of chapters 9, 10, 11, to 10, 11, 12 respectively.)

In present chapter 10 (which has become chapter 11) on Standing Committees, change the specification of the constitution and duties of the Committee of Publication to read as follows: (iv) *The Committee of Publication,* to consist of the Editor, *ex officio,* as Chairman, and three other Fellows, one from each Class, to whom all communications submitted to the Academy for publication shall be referred, and to whom the printing of the Proceedings and the Memoirs shall be entrusted.

It shall fix the price at which volumes of the publications shall be sold; but Fellows may be supplied at half price with volumes which may be needed to complete their sets, but which they are not entitled to receive gratis.

It shall determine when the pressure of material offered for publication makes it necessary to give preference to members of the

Academy as compared with non-members, or to give priority to certain members as compared with others, and to what extent this preference or priority shall be applied in each of the three Classes, to the end that a proper balance of the facilities of publication with respect to subject matter and authors may be maintained.

The President announced the deaths of three Fellows:—Hans Carl Günther von Jagemann (Class III, Section 2), Samuel Jason Mixter (Class II, Section 4), and Henry Newton Sheldon (Class III, Section 1); and of one Foreign Honorary Member:—Sir Sidney Lee (Class III, Section 4).

The President appointed the Nominating Committee as follows:

Edward V. Huntington, of Class I
Reginald A. Daly, of Class II
William C. Wait, of Class III

The following communication was presented:

Mr. Dayton C. Miller: "Ether Drift Experiments," illustrated with moving pictures.

Two papers were presented by title:

"Measurement of the Compressibility of the Alkali Halides," by J. C. Slater. Presented by Theodore Lyman.

"Studies on Ethiopean Braconidae, with a Catalogue of the African Species," by C. T. Brues.

The Meeting was dissolved at 10.20 P.M.

One thousand one hundred and forty-sixth meeting.

MARCH 24, 1926.—OPEN MEETING.

An Open Meeting was held at the house of the Academy from four to six o'clock.

The PRESIDENT in the Chair.

There were present about one hundred Fellows and guests, including ladies.

Mr. Merritt L. Fernald, Fisher Professor of Natural History, Harvard University, spoke on "The Antiquity of Species and their Rate of Evolution as Indicated by the Flora of Boreal America," illustrated with lantern slides.

Tea was served at five o'clock in the Reception Room on the third floor.

One thousand one hundred and forty-seventh meeting.

April 14, 1926.—Stated Meeting.

The Academy met at its House at 8.15 P.M.

The President in the Chair.

There were present twenty-two Fellows and Associates and four guests.

The Records of the Meeting of March 10 were read and approved.

The Corresponding Secretary announced the receipt of a biographical notice of Edward Sylvester Morse, by J. S. Kingsley.

The following communication was presented:

Mr. Edward V. Huntington: "Some Ambiguities in the Present-Day Notation for Musical Intervals and Scales," with lantern illustrations.

The Meeting was dissolved at 9.15 P.M.

One thousand one hundred and forty-eighth meeting.

May 12, 1926.—Annual Meeting.

The Academy met at its House at 8.15 P.M.

The President in the Chair.

There were present forty-one Fellows and Associates, and one guest.

The Records of the Meeting of April 14 were read and approved.

The Corresponding Secretary announced the receipt of biographical notices of William Crawford Gorgas, by E. C. Whipple; and of Nathaniel Southgate Shaler, by A. C. Lane.

The President announced the deaths of one Fellow, Edward Hickling Bradford (Class II, Section 4); and of one Foreign Honorary Member, Johann Oskar Backlund (Class I, Section 1).

The following report of the Council was presented:

Since the last report of the Council there have been reported the deaths of fourteen Fellows:—George Burton Adams, Edward Hickling Bradford, John Mason Clarke, Leslie Colby Cornish, William Otis

Crosby, William Curtis Farabee, Isaac Minis Hays, Albert Andrew Howard, Hans Carl Günther von Jagemann, Samuel Jason Mixter, Edward Sylvester Morse, Edward Stevens Sheldon, Henry Newton Sheldon, Jay Backus Woodworth; and of four Foreign Honorary Members:—Johann Oskar Backlund, Felix Klein, Sir Sidney Lee, Heinrich Müller-Breslau.

Fifteen Fellows and three Foreign Honorary Members, as well as fourteen Associates, were elected by the Council and announced to the Academy in May 1925.

The roll now includes 571 Fellows, 60 Foreign Honorary Members, and fifteen Associates (not including those elected in May 1926).

The annual report of the Treasurer, Ingersoll Bowditch, was read, of which the following is an abstract:

General Fund

Receipts

Income on hand April 1, 1925		$ 2,523.95
From Investments	$3,407.00	
" Assessments	3,380.00	
" Admissions	170.00	
" Sundries	235.88	7,192.88
		$ 9,716.83

Expenditures

Expenses of Library	$1,809.80	
Treasurer's Expenses	821.53	
Books and Binding	1,084.08	
General Expenses	1,081.54	
House Expenses	3,020.20	
President's Expenses	16.51	
Biographical Notices	45.32	$ 7,878.98
Transferred to Publication Funds	$ 250.00	
Income transferred to Principal	389.93	639.93
		$ 8,518.91

Rumford Fund

Receipts

Income on hand April 1, 1925		$ 8,761.89
From Investments	$3,966.94	
" Galvanometer sold	320.00	4,286.94
		$13,048.83

Expenditures

Purchase and Binding of Books	$ 182.40	
Publications	505.00	
Research	1,007.21	
Tables of Constants	200.00	
Medals	314.66	
Sundries	15.00	$ 2,224.27
Income transferred to Principal		180.65
		$ 2,404.92

C. M. Warren Fund

Receipts

Income on hand April 1, 1925	$ 137.49
From Investments	1,118.49
	$ 1,255.98

Expenditures

Research	$ 738.40	
Vault Rent, part	3.00	$ 741.40
Income transferred to Principal		56.29
		$ 797.69

Publicaton Fund

Receipts

Income on hand April 1, 1925		$ 4,342.63
From Income Appleton Fund	$ 590.75	
" " Centennial Fund	2,458.10	
" Authors' Reprints	951.20	
" Sale of Publications	489.40	
" National Academy of Sciences	1,000.00	
" Donation	1,500.00	
" General Fund Income	250.00	$ 7,239.45
		$11,582.08

Expenditures

Publications	$8,345.68	
Vault Rent, part	10.00	$ 8,355.68
Interest on Bonds, bought	30.38	
Income transferred to Principal	144.48	174.86
		$ 8,530.54

Francis Amory Fund

Receipts

From Investments		$ 1,882.50

Expenditures

Publishing Statement	$ 50.40	
Interest on Bonds, bought	29.75	80.15
Income transferred to Principal		1,802.35
		$ 1,882.50

The following reports were also presented:

Report of the Library Committee.

The Librarian begs to report for the year 1925–26, as follows:

During the year 134 volumes and 17 unbound numbers of periodicals have been borrowed by 18 Fellows and 10 libraries, and many more have been consulted at the Academy. All books taken out have been returned or satisfactorily accounted for.

The number of books on the shelves at the time of the last report was 40,048. During the year 431 volumes were added, making the number now 40, 479. This includes 58 purchases from the General Fund, 33 from the Rumford Fund, and 340 received by gift or exchange. The number of pamphlets added was 304.

The expenses charged to the Library during the financial year ending April 1, 1926, are:

Salaries	$1,800.00
Binding:	
General Fund	589.95
Rumford Fund	74.75
Purchase of periodicals and books:	
General Fund	494.13
Rumford Fund	107.65
Miscellaneous	9.80

H. M. Goodwin, *Librarian.*

May 12, 1926.

Report of the Rumford Committee.

The Committee held six meetings during the year (Oct. 14, Dec. 9, Jan. 13, Feb. 4, March 10, May 12).

The Rumford Premium was presented by the President of the Academy to Professor Henry Norris Russell, of Princeton University, for research in stellar radiation, at a meeting of the Academy on October 14, 1925. At this meeting, Professor Russell made a communication on "The Present State of Theories of Stellar Evolution."

The Committee made the following grants during the academic year 1925–26:

Oct. 14. Professor George R. Harrison, Physics Department, Stanford University, Palo Alto, California, for material and apparatus in research on photographic photometry.	No. 254.	$ 350
Oct. 14. Professor Harlan T. Stetson, Astronomical Laboratory, Harvard University, for an instrument in the measurement of coronal radiation	No. 255.	120
Dec. 9. Professor John R. Roebuck, University of Wisconsin, Madison, Wisconsin, for apparatus for the measurement of the mechanical equivalent of heat. . .	No. 256.	275
Mar. 10. Professor Harlow Shapley, Harvard College Observatory, Harvard University, towards the construction of a thermal electric micro-photometer for stellar work.	No. 257.	500
May 12. Professor George W. Pierce, Harvard University, for photo-electric research.	No. 258.	200
		$1,445

Since the date of the last Committee report, information concerning the researches completed with aid from the Rumford Fund, has been received from the following persons:—Harlow Shapley, Farrington Daniels, George S. Forbes.

The following paper has been published by the Academy, with the aid of the Rumford Fund:

"Joule-Thomson Effect in Air," by J. R. Roebuck.

The following papers published elsewhere covering researches aided from the Rumford Fund have been published since the date of the Committee's last report:—

"An Application of X-Ray Crystallometry to the Structure of Nickel Catalysts," by George L. Clark, W. C. Asbury and R. M. Wick.

"The Constricted Mercury Arc as a Source of Light for Photochemical Work," by George S. Forbes and George R. Harrison.

"Spectral Energy Characteristics of the Constricted Mercury Vapor Lamp—An Extremely concentrated Source of Ultraviolet Illumination," by George Shannon Forbes and George R. Harrison.

"Relations Involving Internal Pressure, Intensity, Mercury Trans-

fer, Cross Section, and Electrical Conditions in Mercury Vapor Lamp," by George Shannon Forbes and Philip Albert Leighton.

"Irregularities in the Specific Heats of Certain Organic Liquids," by John Warren Williams and Farrington Daniels.

"The Specific Heats of Certain Organic Liquids at Elevated Temperatures," by John W. Williams and Farrington Daniels.

On March 10, the Committee reported for the first time, unanimously, and on May 12 for the second time unanimously, to recommend to the Academy the award of the Rumford Premium to Arthur Holly Compton for his researches in Röntgen Rays.

The review of the history and aims of the "Rumford Fund" was published on behalf of the Committee, in "Science," February 26, 1926, page 223, Vol. 63, No. 1626.

A. E. Kennelly, *Chairman.*

May 12, 1926.

Report of the C. M. Warren Committee.

The Committee had at its disposal at the beginning of the fiscal year 1925–26, $1,189.32. The estimated available income for the year April 1, 1926, to April 1, 1927, is $1,061.39.

Since the last annual report awards have been made as follows:

November 11, 1925: To Dr. Ben Corson, Middlebury College, $200.00, to be used in the purchase of apparatus and chemicals in connection with the study of the condensation reactions of benzoylformic and mesoxalic esters.

November 11, 1925: To Professor James B. Conant, Harvard University, $500.00, for the purchase of apparatus and supplies to be used in an electrochemical investigation of oxidation processes.

April 16, 1926: To Dr. Louis F. Fieser, Bryn Mawr College, $170.00, to cover the cost of electrical apparatus required for the study of certain organic reduction potentials.

April 16, 1926: To Professor Ralph H. Bullard, Hobart College, $300.00, for the purchase of supplies in connection with a research on organic tin compounds.

Reports of progress have been received from Prof. Conant, Dr. Allen and Dr. Fieser.

James F. Norris, *Chairman.*

May 12, 1926.

Report of the Committee of Publication.

The Committee of Publication reports as follows for the period Oct. 14, 1925, to March 31, 1926.

During this period six numbers of the Proceedings and one Memoir have been published, and six numbers of the Proceedings are now in press.

The printing of one number of the Proceedings has been paid for from the Rumford Fund and one now in press is to be paid for from the Rumford Fund.

The donation of $1,000 from the National Academy of Sciences is to be used for the printing of particular papers and these papers are to carry a notice to the effect that they are published from Funds donated by the National Academy of Sciences. Copies of these papers will be sent to the Secretary of the National Academy.

The financial report for the fiscal year April 1, 1925, to March 31, 1926 is as follows:

Receipts

Income on hand April 1, 1925		$4,342.63	
From Income Appleton Fund .	$ 590.75		
" " Centennial Fund .	2,458.10		
" Authors' Reprints . . .	951.20		
" Sale of Publications. . .	489.40		
" National Academy of Sciences	1,000.00		
" Donation.	1,500.00		
" General Fund Income . .	250.00	7,239.45	$11,582.08

Expenditures

Publications	$8,345.68		
Vault Rent, part	10.00	$8,355.68	
Interest on Bonds, bought. . .	$ 30.38		
Income transferred to Principal .	144.48	174.86	$ 8,530.54
Balance on hand March 31, 1926			$ 3,051.54

Respectfully submitted,

Wm. S. Franklin, *Chairman.*

May 12, 1926.

Report of the House Committee.

The House Committee has had funds at its disposal amounting to $3,453.83, made up as follows:

Balance from last year	$ 273.83
Appropriation for 1925–26	3,000.00
Received for use of rooms	180.00
	$3,453.83

Of this amount, the sum of $2,456.53 has been spent for the usual routine expenses, janitor, light, power, heat, telephone, etc., which differ but slightly from year to year, and $743.67 has been spent for upkeep, making a total of $3,200.20, and leaving an unexpended balance of $253.63.

The total outlay for the routine expenses was $193.71 less than for last year and for upkeep, $477.67 more than last year. The two largest items in the upkeep expenses are for repairs to the hot water boiler and for painting the reading room, the halls of the upper floors, and the outside window frames and sashes all over the building.

Our appropriation for the coming year includes a sum for painting the entrance hall, the rooms on the ground floor, and the office, which work we expect to have done during the summer.

Meetings have been held as follows:

The Academy	
Stated meetings	8
Open meeting	1
American Antiquarian Society	1
Archaeological Institute of America	2
Colonial Society	4
Harvard-Technology Chemical Club	6
New England Botanical Club	10
Mediaeval Academy of America	1
	33

The Council Chamber has been used for Academy Council and

Committee meetings, and also by the Colonial Society, the Trustees of the Children's Museum, and the Thursday Evening Club.

A detailed list of expenditures follows:

Janitor		$ 973.00
Electricity	Light	189.98
	Power	61.74
Coal		931.36
Care of elevator		60.64
Gas		61.08
Water		24.64
Telephone		87.00
Ash tickets		30.15
Upkeep		743.67
Furnishings and equipment		17.68
Janitor's supplies and sundries		19.26
Total expenditures		$3,200.20

Respectfully submitted,

WM. H. LAWRENCE, *Chairman.*

May 12, 1926.

On the recommendation of the Treasurer, it was

Voted, That the Annual Assessment be $10.00.

On the recommendation of the Rumford Committee, it was

Voted, To award the Rumford Premium to Professor Arthur Holly Compton, of the University of Chicago, for his researches on Röntgen rays.

The annual election resulted in the choice of the following officers and committees:

THEODORE LYMAN, *President.*
ARTHUR E. KENNELLY, *Vice-President for Class I.*
WILLIAM M. WHEELER, *Vice-President for Class II.*
ARTHUR P. RUGG, *Vice-President for Class III.*
ROBERT P. BIGELOW, *Corresponding Secretary.*
CHARLES B. GULICK, *Recording Secretary.*

INGERSOLL BOWDITCH, *Treasurer.*
HARRY M. GOODWIN, *Librarian.*
WILLIAM S. FRANKLIN, *Editor.*

Councillors for Four Years.

HARLOW SHAPLEY, *of Class I.* LOUIS C. GRATON, *of Class II.*
EDWARD H. WARREN, *of Class III.*

Finance Committee.

THOMAS BARBOUR PAUL J. SACHS FREDERICK P. FISH

Rumford Committee.

ARTHUR E. KENNELLY

ELIHU THOMSON
PERCY W. BRIDGMAN
HARRY M. GOODWIN
CHARLES L. NORTON
HARLOW SHAPLEY
FREDERICK A. SAUNDERS

C. M. Warren Committee.

JAMES F. NORRIS

HENRY P. TALBOT
ARTHUR D. LITTLE
WALTER L. JENNINGS
FREDERICK G. KEYES
GREGORY P. BAXTER
REID HUNT

Publication Committee.

(Editor) WILLIAM S. FRANKLIN, *ex officio Chairman*
EDWIN C. KEMBLE, *of Class I.* HERBERT V. NEAL, *of Class II.*
GEORGE F. MOORE, *of Class III.*

Library Committee.

(Librarian) HARRY M. GOODWIN, *ex officio Chairman*
RAYMOND C. ARCHIBALD, *of Class I.* THOMAS BARBOUR, *of Class II.*
WILLIAM C. LANE, *of Class III.*

House Committee.

WILLIAM H. LAWRENCE, *Chairman*
ROBERT P. BIGELOW S. BURT WOLBACH

Committee on Meetings.

THE PRESIDENT
THE RECORDING SECRETARY
GEORGE H. PARKER GREGORY P. BAXTER WILLIAM C. GREENE

Auditing Committee.

GEORGE R. AGASSIZ JOHN E. THAYER

The Council reported that the following gentlemen were elected members of the Academy:

Class I, Section 1 (Mathematics and Astronomy):
Norbert Wiener, of Cambridge, as Fellow.
Class I, Section 2 (Physics):
Walter Guyton Cady, of Middletown, Conn., as Fellow.
Class I, Section 3 (Chemistry):
Roger Adams, of Urbana, Illinois, as Fellow.
Class II, Section 1 (Geology, Mineralogy and Physics of the Globe):
Edward Bennett Mathews, of Baltimore, Md., as Fellow.
Class II, Section 3 (Zoölogy and Physiology):
Edwin Joseph Cohn, of Cambridge, as Fellow.
Class II, Section 4 (Medicine and Surgery):
George Richards Minot, of Boston, as Fellow.
Class III, Section 2 (Philology and Archæology):
Herbert Joseph Spinden, of Cambridge, as Fellow.
Class III, Section 4 (Literature and the Fine Arts):
Frank Weston Benson, of Salem, as Fellow.
Associates:—Howard M. Buck, John A. Cousens.

The following communication was presented:

Mr. George P. Baker: "Problems of the Dramatist."

The following paper was presented by title:

"Contribution towards a Monograph of the Laboulbeniaceæ, Part IV," by Roland Thaxter.

The Meeting was dissolved at 10.05 P.M.

BIOGRAPHICAL NOTICES.

WILLIAM CRAWFORD GORGAS (1854–1920).

Fellow in Class II, Section 4, 1918.

Professor George C. Whipple had agreed to prepare the memorial to General Gorgas, but was waiting for some data from Mrs. Gorgas when his own death came and cut short his many-sided activities. Rather than reassign the memorial, it seems best to print a paragraph that he had prepared and add from his papers reference to the tribute to General Gorgas which, appearing in the New York Times, was copied in "Science," Oct. 13, 1922. There was also a memorial entitled "Death of a Hero" in "How to Live," Aug. 1920, vol. III, no. 8. Professor Whipple also evidently intended to refer to two papers on Public Sanitation and the Single Tax, by General Gorgas and Professor L. J. Johnson, issued by the Joseph Fels Fund of America at Cincinnati. The authoritative biography of Gorgas is, of course, that prepared by his widow in collaboration with Burton J. Hendrick, and published by Doubleday, Page and Company.

A. C. L.

As a sanitary engineer I wish to pay my tribute to General Gorgas. His methods of promoting and applying scientific knowledge to the control of insect-borne diseases opened up a new field of sanitation and demonstrated that the white man can successfully inhabit tropical lands. For centuries the drift of the earth's white population has been away from the equator; the coming century may see the beginning of a return movement. Western peoples have been multiplying at the average rate of about 1.1 per cent. a year and this rate has probably been exceeded by the Asiatic peoples. Either there must be expansion of habitable areas or great conflicts between races. Whoever makes possible the settlement of new lands contributes to the world's peace. Gorgas, medical entomologist and sanitary engineer, has accomplished this. First at Havana, then later in other parts of the world, his work was done thoroughly and successfully. Although the Panama work was expensive, it was worth its cost many times over.

George C. Whipple.

ALFRED MARSHALL (1842–1924).

Foreign Honorary Member in Class III, Section 3, 1916.

Alfred Marshall, the most distinguished among English-speaking economists of his time, and probably the most distinguished of any nationality, was born July 26, 1842 and died July 13, 1924. He graduated at Cambridge University (St. John's College) as Second Wrangler in 1865; was Fellow and Lecturer at St. John's for some years, then Professor of Political Economy at Bristol, and for one year Fellow and Lecturer at Oxford (Balliol); finally, from 1884 to his retirement in 1908, Professor of Political Economy at Cambridge.

By far the most important of his works is the Principles of Economics, published in 1890 (8th ed. 1920). It was planned to be the first volume of a comprehensive treatise, but this plan was never carried out. Toward the end of his life, however, two further large volumes appeared, which in a measure fulfilled the original design; one on Industry and Trade, 1919, another on Money, Credit, and Commerce, 1923. His publications also include a number of articles, addresses, memoirs, and evidence given before government commissions. Of all these a complete list is given in an admirable Memoir by J. M, Keynes (1924).

The Principles of Economics secures for Marshall a place in the history of the subject comparable to that of Adam Smith and Ricardo. In originality and intellectual nicety his work is superior to that of John Stuart Mill, who had in his day a position no less commanding. Marshall belongs in orderly succession to the British School, and is rightly described as a neo-classicist. He marks no radically new departure; he develops, supplements, enlarges, corrects. But the development and enlargement are so great as to make the structure virtually new. Every topic handled by him, both in the Principles and in the other books, shows the touch of a fresh, keen, far-reaching mind. Whether it was the theory of value and distribution or that of national wealth and national welfare, international trade, monopoly and taxation, the methods of economics, or the relations of economics to other sciences,—nowhere is there unquestioning acceptance of traditional doctrines. With a just and even generous recognition of what was sound in the older views, there is everywhere originality of treatment, and modification with improvement.

Marshall's influence therefore is writ large in almost everything that comes nowadays from the economists—at least from those who write in English. Many of his turns of phrase have become household words,—demand schedules and supply schedules, the equilibrium of supply and demand, short-period and long-period equilibrium, internal and external economies, the representative firm, quasi-rent, consumer's surplus and total utility; these have become part of the stock in trade of every teacher and student. But they are more; they are crystallizations of trains of reasoning and of substantive conclusions which have become imbedded in the structure of economics.

Marshall's influence in Great Britain was commanding, and hardly less so in the United States. In all countries it was very great. He founded a school, or at least nurtured a notable group of economists; a skilled and highly trained school, at once theoretical and practical. It combines refined analysis and theoretic nicety with a hunger for facts and for the explanation of facts. Marshall's influence has done more to bring economics toward the position of an exact science than has been the case with any other thinker on this subject. His precision of reasoning was aided by his command of mathematics, and the applications of mathematical methods to economic problems at his hands are among the notable achievements of the intellect. And not less notable was the circumstance that Marshall—able as he was to use the mathematical tool with perfect skill—rather underestimated than overestimated its serviceability in solving the complicated substantive problems of economics.

The temperament of the man was in every respect that of the scientist. He preached no gospel. This is not to be understood as intimating that he was indifferent to the question of social justice. His feelings were warm and generous, and he was far from being a defender of things as they are. But his attitude was that of the man of science and not that of the preacher. Everywhere in his work is the mark of a thinker who is independent and ingenious, yet measured and judicious. With it all went great modesty and self-effacement; no trace of ostentation, no emphasis or even hint of the originality or significance of his own contributions. The history of science shows no more admirable spirit.

F. W. Taussig.

EDWARD SYLVESTER MORSE (1838–1925).

Fellow in Class II, Section 3, 1869.

Edward Sylvester Morse, son of Jonathan K. and Jane Seymour (Beckett) Morse, was born in Portland, Maine, June 18, 1838, and died in Salem, Mass., December 20, 1925.

After his earlier years in the common schools of Portland, he spent three years in Bethel and Bridgeton (Me.) academies, incorporated schools of the better class which were so common in all New England in the middle of the last century. On leaving these institutions he entered the employ of the Maine Central Railroad as draftsman in the locomotive shops, a position for which he was well fitted by that skill with pen and pencil which later stood him in such good stead.

At that time the Portland Society of Natural History, an organization which still exists, was in full vigor, and he joined it, as he had been, from his earliest years, interested in every aspect of nature. Here he came in contact with Dr. William Wood, Charles Fuller and Rev. Edwin C. Bolles, all enthusiastic naturalists, and encouraged by them, he began the study of the land shells of the state. His studies soon brought him into correspondence with the leading conchologists of the time—Drs. Michels, A. A. Gould, Amos Hinney and his son, William G., as well as with several in New York and Philadelphia. In his spare hours he visited the woods of the region and the islands of Casco Bay, and found there several new species of land snails, descriptions of which were published in scattered papers; the substance of all of these was brought together in a well illustrated paper issued in the first volume of the Journal of the Portland Society in 1864.

By his labors as draftsman for the railroad company he accumulated money enough to drop the engineering work and so he went to the Lawrence Scientific School at Harvard to study with Louis Agassiz, and here he remained during the years 1859 to 1862. He had as fellow students, among many others, Caleb Cooke, Alpheus Hyatt, Alpheus Spring Packard, Jr., Frederick Ward Putnam, Samuel Hubbard Scudder and Addison Emery Verrill, all of whom attained prominence as zoologists. All now, Verrill excepted, are with the majority.

When he finished his studies he was appointed an assistant in the Museum of Comparative Zoology, a position he held until his removal

to Salem. During these years at Cambridge and Salem, the state of Massachusetts was preparing a new edition of A. A. Gould's Invertebrata of the state and Morse was employed to draw the illustrations of the shells, and all who are familiar with that work recognize at once his mastery of his pencil (the illustrations were drawn reversed upon the wood for the engraver), and the accuracy of his observations.

In the early sixties Salem was a scientific centre and the Essex Institute was one of the active publishing societies. The Salem shipmasters brought home large collections in the lines of zoology, botany and ethnology and these enriched the museum of the Institute. Through the influence of Fred Putnam, a native of Salem, five of these students of Agassiz were called there to work up the collections. Their special lines fitted them well to work together. Putnam was a student of vertebrates. Packard had devoted himself to the Cuverian group of Articulata, Morse was a malacologist and Hyatt studied sponges and geology, while Verrill, who was soon called to Yale, looked out for the so-called Radiata.

Then came the gift of the London banker, George Peabody, of $140,000, a princely sum in those days, to found a new institution, the Peabody Academy of Science, in Salem. This was to acquire the buildings and anthropological collections of the East India Marine Society, rich in objects from the East and the South Seas, and the biological collections of the Essex Institute. With the establishment of the Academy in 1867, Hyatt, Morse, Packard and Putnam were placed in charge of its scientific activities, each with his special duties.

One of their first acts was to start the publication of the American Naturalist, a monthly journal which for many years was the only periodical devoted to semi-popular natural history in the country. All four were its editors, but Morse and Packard were the more prominent in its management and were its chief contributors. Many a young naturalist of those days got inspiration from a series of articles, written and illustrated by Morse, on the mollusca, including a brief account of the common clam and detailed descriptions of the land shells of New England.

In those early years in Salem Morse turned his skill in drawing in another direction. Those were the days of the lyceum and many a town had its regular lecture course, and Morse was soon in demand for

a popular lecture with blackboard illustrations, often going as far as the Mississippi to please and instruct his audiences, describing the familiar objects of the neighborhood and pointing out new things in the very animals which people thought they knew. His ambidexterity held the closest attention of his listeners, and he also had something to say. He was one of the first in this country to accept evolution and many of his chalk talks were upon that subject, and without doubt he did more than anyone else to bring the great mass of the thinking people of America to the acceptance of Darwin's work. His illustrations, verbal or on the blackboard, were always apt and readily understood. His humor sparkled through it all, and again and again he lectured before the same organizations, ample evidence of his power to please.

In the seventies of the last century the authorities of the University of Tokyo determined to put the institution on the same scholarly basis as the best of the European schools, and with other Americans Morse was selected as a member of the faculty, and from 1877 until 1880 he occupied the chair of zoology there, and laid the foundation of that love for Japan and its people which characterized him through life. He inspired the greatest enthusiasm in his students there, and the world owes directly to him the scientific work of Mitsukuri and Ishikawa, as well as that of the long line of their pupils, Watase, Oka, Goto, Myabe, Yatsu and many others. While in Japan, besides organizing his department and beginning a zoological library for it, he studied the Brachiopods of the Japanese seas and investigated the shell-heaps and the old cave dwellings of the empire, and demonstrated that in Japan, as in other countries, there had been a well-marked stone age in the history of the islands. He also laid the foundation of his collection of the work of the Japanese potters which he greatly enlarged and improved on a subsequent visit when he was fortunate in not only picking up numbers of the classic Japanese books on pottery, but also in getting some of the very specimens figured in the works of Ninigawa and other writers on the subject. The study of these pots and vases led him not only into a study of the tea ceremonies, but to take up in a way the subject of Chinese hieroglyphics so that he might recognize the better the various potters' marks. The collection he accumulated was one of the largest and probably the

most thoroughly representative of any in the world concerned wholly with the Japanese potters' art. It was purchased some years ago by the Boston Art Museum for $76,000 and it now forms an important element in their collections. In 1892 the Museum appointed him keeper of the department, a position on the staff which he held until his death.

When Morse returned from Japan in 1880, there was a vacancy in the directorship of the Peabody Academy and he was elected to the position, holding it until the end. He began at once a rearrangement of the collections, was successful in raising money to enlarge the building; and the result is one of the most interesting and instructive museums in the country, especially in anthropological lines. He worked out the scheme of arrangement, devised new methods of display, new types of cases, and composed labels which mean something to even the most casual visitor.

It is difficult to summarize his zoological work, for a zoologist he remained until the end. Possibly his most important papers were those relating to the Brachiopoda, a group which, when he began to study it, was all but universally regarded as molluscan, rather closely related to the oyster and the clam. Almost immediately he saw the bearing of certain facts of structure, the significance of which had been overlooked by his predecessors. As these animals have two halves or valves to the shell, this resemblance to clams had obscured all else. Morse showed that this was not a true resemblance, for the valves of the clam are right and left, while those of the Brachiopods are dorsal and ventral. Then he took up the study of the internal organs and the development of the eggs, making trips to Eastport and to the North Carolina shore for his material. Every fact he found confirmed him in his conclusions, now universally accepted, that these animals are far more closely related to the common earthworm than to any mollusc. Less striking, but important, was his study of the ankle bones of birds in which he showed that a slight splint was in reality one of the separate bones which occurs in the whole group of reptiles.

Morse was honored by membership in numerous scientific societies. He was Vice-President of the American Association for the Advancement of Science in 1883, President in 1886; a member of the National Academy of Science; President of the Boston Society of Natural

History for several years; and member of many societies both in this country and in Europe and the east. He was twice decorated by the Japanese government, receiving, first, the order of the Rising Sun; second, that of the Sacred Treasure. He received the degree of master of arts from Harvard, doctor of philosophy from Bowdoin College, doctor of science from Yale and doctor of humane letters from Tufts. He was on the juries of award for the Chicago, Buffalo and St. Louis expositions.

But there is another side to Professor Morse which we like to recall. He was intensely human. He was always ready to help any young naturalist, and was never too busy to give his time to any boy who came to him with some scientific question. He loved the company of his fellow men, and while a student under Agassiz he and a few others organized the Boston Naturalists' Club, (intended to get together in good fellowship any and all lovers of natural history in its broader sense), whose recent demise is greatly deplored by many of its former members. The club had but a single officer who acted as secretary and treasurer and whose chief duty was to keep a lookout for the visiting scientist and have him as a guest of the club. Set speeches were taboo at the dinners; the guest had only to become acquainted with the members present, and when Morse was there, there was no lack of interesting conversation, for he always had some new story, some play on words, or some recent incident to relate, and all with a scientific turn.

Wherever he went his eyes were open, noticing many a thing which others would neglect. What he saw he noted down with drawings in the notebook he always had at hand. The result, sooner or later, was a series of informative essays or a book. Thus he published in one of the architectural magazines a series on roofing tiles in different parts of the world where his travels had taken him; another on the latrines of the east. He noticed the way in which Japanese archers let the arrow fly, and this was followed up by studies of the methods of arrow release in different times and among various peoples in all parts of the world, studies which threw light on old inscriptions which had long been troublesome to archaeologists. On his first trip to Japan he made notes and sketches of everything he saw in the streets, in the houses, and in the country. Years later he resurrected these and

published them in a book, the original drawings being reproduced just as they were noted down, the result being a vivid picture of a Japan which even now is largely gone as a result of contact with foreign nations. A short trip in China had similar results.

In his work Morse was handicapped by a limited knowledge of foreign languages and much that was written by the continental zoologists was practically unknown to him. I recall his saying, in the seventies, that he was going to desert the Mollusca as a field of study because there was practically nothing more to be done on the group aside from describing new species. Since that time our whole conception of these animals has been changed by the work of Lankester, von Ihering, Grobben, Pelseneer, Plato and others.

Morse had few animosities, but he hated two things—noise and flies. The fly which entered his study was inviting certain death. He fought railway whistles, engine bells and all sorts of noises, and often the result was a bettering of conditions for mankind. It is said that his crusade indirectly resulted in curbing the whistles of the tugs in New York harbor. In his early years when on his lecture tours, he was often entertained by people in the town. In Cincinnati, where he was the guest of a prominent family, he was annoyed, after retiring, by the persistent ticking of a small but valuable clock in his room. He tried every way to stop it, but in vain. Sleep was impossible, so at last he wrapped the clock in his laundry and packed it away in his suitcase, went to sleep and forgot all about it until twenty-four hours later he unpacked again in Columbus and, to his horror found the offending timepiece. He was afraid he would be considered a thief, so early the next morning a telegram was sent and the clock followed by express.

As has been intimated above, he was an artist and an ambidextrous one. He would draw with either hand, accordingly as he picked up the pencil but some of the stories told of him are not justified by the facts. He could not write two words at the same time, nor could he draw two pictures at once. But his drawing of symmetrical objects with both hands was always a striking feature of his lectures, although the feat is not difficult. Like many other artists he wrote a miserable hand, but he improved greatly in his later years in this respect. He took a sort of pleasure in his shortcomings and for a long time he used

to read to his friends a letter from T. B. Aldrich to the effect "Now I've got a spare afternoon and I'll have another whack at the letter I received from Ned Morse some months ago."

He also had a whimsical turn of mind, was always trying queer experiments, none of which was more amusing than one related by Dr. Thomas Barbour. "Only a few years ago I found him trying to play a flute with his nose. 'When the Soloman Islanders do it, why shouldn't I?' "

There are few left like Edward Sylvester Morse today. Our zoologists are specialists, and know but little outside their limited fields. Morse was interested in every side of the subject, and could talk intelligently on its every aspect. He was eager for more knowledge in every line and his questions always showed a basal information upon which he could build, and what he learned he retained.

J. S. KINGSLEY.

JAMES JACKSON PUTNAM (1846–1918).

Fellow in Class II, Section 3, 1878.

Dr. James Jackson Putnam was born Oct. 3, 1846, and died Nov. 8, 1918. The facts of his life are outlined in Volume XI. and previous volumes of Who's Who. We abstract an interesting tribute by Dr. E. W. Taylor that appeared in the Archives of Neurology and Psychiatry, March 1920, Vol. III, pp. 307–314. He was the last survivor of the group of seven who founded the American Neurological Association in 1875, its president in 1888.

Although a pioneer in neuropathology, whose laboratory in his own house "may well be regarded as a forerunner" of that at the Harvard Medical School, "he never stagnated: interest in the past lay for him in its significance for the future; his zeal for progress and his optimistic hope in new discovery were the keynotes of his energetic life and career."

He championed the entrance of women into medical schools, and "was strongly attracted by the work of Freud and his associates, "for the last ten years of his life he gave himself over, with characteristic enthusiasm to the task of reconciling the materialism or pessimism of Freud with his own unquenchable optimism and with the

moral purpose of the World in which he so strongly believed, "striving with such help as he could get to work out a satisfactory theory of life in which the conflicting claims of exact science and philosophy and religion might in some degree be brought into accord."

For the rôle he played in divers good causes, for the outline of his technical work in neurology and psychotherapy, and in showing up the effects of lead and arsenic poisoning, for his relations to his friends, Weir Mitchell, H. P. Bowditch, O. F. Wadsworth and William James, reference may be made to Dr. Taylor's article.

His father was Dr. Charles Gideon Putnam, a distinguished physician, whose father Samuel was Judge of the Supreme Court of Massachusetts. His mother, Elizabeth Cabot Jackson, was daughter of Dr. James Jackson.

He is said to have been an "incorrigible idealist who believed deeply in the beneficent ordering of the world," whom President Lowell characterized as "a man of science eminent in his field, a philosopher and a saint."

A. C. Lane.

GUSTAF MAGNUS RETZIUS (1842–1919).

Foreign Honorary Member in Class II, Section 3, 1907.

Gustaf Magnus Retzius was born in Stockholm, Sweden, October 17, 1842, and died there July 21, 1919. Like the Munros of Scotland his was a family of anatomists and natural historians. His grandfather, Anders Johan Retzius, was professor at Lund and his father Anders Adolf Retzius was the well known anatomist and anthropologist of Stockholm. Young Retzius gained his academic training in Upsala and Stockholm and established himself in Lund in 1871 where he succeeded to the chair of anatomy. By 1890, however, he had resigned his academic connections to devote himself exclusively to his chosen line of scientific research. In this few scholars have equalled his enormous productiveness.

Already as early as 1876 he published in collaboration with Axel Key his extended account of the anatomy of the nervous system and its membranes. This was followed a few years later by his exhaustive studies on Finnish crania. In 1881 and 1884 appeared his two volumes

on the internal ears of vertebrates. These folios with their exquisite illustrations, almost all directly from the hand of Retzius, represent the high-water mark of micro-anatomical description and are still the authoritative source for much that is known of the vertebrate ear. Then followed two beautifully illustrated volumes on the gross anatomy of the brain of man to which was added a few years later an exhaustive description of the monkey brain. Meanwhile the crania of ancient Sweden had received a monographic treatment.

As though this prodigious output were not enough Retzius published a running series of folios under the general title of "Biologische Untersuchungen." Each folio contained from six to twelve contributions touching a great variety of anatomical subjects. They were, however, chiefly noteworthy for their elucidation of the nervous system and for the support that they gave to the then novel neurone theory of Waldeyer. Retzius was quick to seize upon and use with great skill the Golgi method of impregnating nervous tissue with silver deposits and the equally important method of Ehrlich for staining nervous elements by means of methylen blue. Both these methods were successfully and industriously applied by him with the result that an enormous step forward was made in our knowledge of the structure of the nervous systems of the worms, the crustaceans, the mollusks, as well as of the higher animals. In this direction alone no single investigator can compare with Retzius in the accuracy and the extent of his observations.

As an exponent of anatomy Retzius stands easily among the first and yet this preëminence in no way interfered with a gentle and modest personality, a characteristic recognized by all who had the good fortune to know him at first hand.

G. H. Parker.

NATHANIEL SOUTHGATE SHALER (1841–1906).

Fellow in Class II, Section 1, 1869.

The Academy memorial of N. S. Shaler was fittingly assigned to J. B. Woodworth by right of an association of thirty years. But the very wealth of knowledge, the help which he gave in the settling of the Shaler affairs and distribution of his library, his association with

the preparation of the Autobiography by Mrs. Shaler (Houghton, Mifflin & Co., 1909), and perhaps above all the impossibility of giving any adequate tribute to the many sided Shaler in the brief space allotted to the Academy memorials, delayed the doing of the task until the solemn messenger came for him also.

Men better fitted than I have already given their tributes,[1] so that it may not be amiss even at this late date if I add my tribute to one to whom it is largely due that I am a geologist, and glean from my memory a story or two, from his letters to me a characteristic sentence.

Prof. N. S. Shaler, born in Kentucky, February 20, 1841, died April 10, 1906, in Cambridge "was the one of my American students I love best" said L. Agassiz. He was no mere savant or philosopher but a man to whom nothing human was alien. In his rich experiences as child of a rich planter, student of Agassiz, Bachelor of Science (Summa Cum Laude) captain of Artillery and a married man before he was 22, afterwards in charge of lumbering, Collector of Internal Revenue, field geologist, mining expert, Director of the Kentucky Geological Survey, of the Commission that organized the State Highway movement in Massachusetts, worker for the U. S. Coast Geodetic and Geological Surveys, traveller, lecturer, magazine writer, story teller, poet, a judge of fighting cocks and horses, a good shot, of much athletic ability, he had met all sorts and conditions of men who recognized him as a fellow man. For forty odd years he was one of the glories of Harvard. In November 22nd, 1885, he wrote me, "My classes are very large (Geology) 4–237, 8–43, 14–23, 16–9." The greatest numbers were more than double.

His lectures amused, interested and stimulated the imagination, were more philosophic and suggestive than informative.

As in the biography there is no letter to a graduate student working under his direction, it may be worth while to give a specimen in full.

"Cambridge, Nov. 26, 1886.

"My dear Mr. Lane:

"I have never been so busy as in the three weeks since your letter came to me.

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[1] J. E. Wolff for the Geological Society of America, Bulletin G. S. A. 18: pp. 592–608.

"Our 250th celebration was the last of many last straws on the patient camel's back.

"I have turned over the matter of your inquiries, and find your suggestions very good. To them I would add the following propositions:

"1st, that you should add to your inquiries matters concerning cements. We are not well off for cements in this country. Our best still come from Europe under the name of Portland Cement which is no longer, I believe from Portland, but (I believe) from Scilley near Boulogne sur Mer in France. The goodness of this remarkable cement depends upon the formation of the double silicate of lime and aluminum caused by the high heat of calcination.

"Portland cements are also made in Germany (?) by a dry process. Find out the history of these processes and if convenient see them in operation.

"The best field for economic results in this country is doubtless in cements and flagstones. I know one good or at least promising flagstone locality which I will tell you of when you return. There are some promising ones on the coast of Maine.

"Examine the Museums of building stones especially that of Jonmeyer, St. London. We can perhaps do something of the sort here.

"Learn all methods of testing.

"Look up the work of a certain Wertheim. I remember seeing a book of his on the subject of strength of materials which contained a method of testing the elasticity of stones by tusim. It was twenty years, or more, ago and I have forgotten the title. I had but a passing glance of it.

"As for roads we are not up to them but soon will be. The ilmenite of Iron Hill, R. I. will make a superb road stuff, about all it is good for, it will oxidize enough to bind together, and I believe that it could be introduced for Boston pavements. It wears like cast iron. We will talk of this when you return. Get what books and papers you can concerning building stones, cements, rock materials, etc., and lists of such as you cannot procure. If convenient add slate to your inquiry, also artificial stones, though I have a poor opinion of them in this climate. Still they are worth attention in passing. You will learn nothing of value from European methods of quarrying. Still you'd best examine them critically for purposes of comparison.

"I shall be glad to see you back full of learning and it may be that at first you will have to take up with economic side, but I am sure the scientific will be foremost in your thoughts.

Yours most truly,

N. S. Shaler."

I do not think we were as intimate as one might expect from the fact that I took my degree in geology after about seven years connection with Harvard. I was a Puritan, the son of Puritans and the grandson of an Abolitionist, and anyone who reads his life will realize that Shaler was of quite other stock. Then again, I was fairly self-sufficient, and Shaler's interest and helpfulness I think went out especially to those who were in trouble, whether in mind, body or estate. Yet we did have many pleasant chats and I enjoyed my excursions and other contact with him, more than I can well tell. He probably had more influence over my life than any other of my teachers.

He told me that he was at one time a vestryman of an Episcopal church, but that they got there a rector who wished to make the church more popular and get in people who were somewhat poorer. This was frowned upon by the majority and Shaler was so disgusted that he lost interest.

Several times he spoke to me about work for somebody who was in trouble. No names were, of course, mentioned.

Shaler's poetic ability is shown by his Shakespearian tragedy, "Elizabeth of England," as well as other poems. His strong imagination, a most useful quality in science, was curbed by a sense of humor. Once in January when "mark down" sales are common he told me that he found every year that he had left over a job-lot of hypotheses that he would sell very cheap. At another time, he said he never introduced anything in his lectures that he had not known for at least two years, since before lecturing on a subject it should be well assimilated. I think this was intended as good advice to me. I doubt if he strictly obeyed his own advice.

Of his last illness Prof. John E. Wolff wrote me at the time, "Professor Shaler's death leaves us somewhat dazed. Two days before his death he seemed to be coming out all right, then pneumonia

suddenly set in in the lung which had not been attacked and it was all over.

"All through his sickness he showed the same brave spirit and grit we are familiar with, often joking with the doctors and friends, and never giving up until the end. His funeral was the most impressive at Harvard in a generation, the students standing in long lines from the house to the chapel."

A. C. LANE.

American Academy of Arts and Sciences.

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Charles McLean Andrews	New Haven, Conn.
John Spencer Bassett	Northampton
Carl Lotus Becker	Ithaca, N. Y.
Charles Jesse Bullock	Cambridge
Thomas Nixon Carver	Cambridge
Edward Channing	Cambridge
John Bates Clark	New York, N. Y.
Archibald Cary Coolidge	Boston
Richard Henry Dana	Cambridge
Clive Day	New Haven, Conn.
Davis Rich Dewey	Cambridge
Ephraim Emerton	Cambridge
Henry Walcott Farnam	New Haven, Conn.
Max Farrand	New York, N. Y.
William Scott Ferguson	Cambridge
Irving Fisher	New Haven, Conn.
Worthington Chauncey Ford	Cambridge
Edwin Francis Gay	Cambridge
Frank Johnson Goodnow	Baltimore, Md.
Evarts Boutell Greene	New York, N. Y.
Arthur Twining Hadley	New Haven, Conn.
Albert Bushnell Hart	Cambridge
Charles Homer Haskins	Cambridge
Charles Downer Hazen	New York, N. Y.
George La Piana	Cambridge

Abbot Lawrence Lowell	Cambridge
William MacDonald	New York, N. Y.
Charles Howard McIlwain	Cambridge
Roger Bigelow Merriman	Cambridge
Samuel Eliot Morison	Concord
William Bennett Munro	Boston
Charles Lemuel Nichols	Worcester
James Ford Rhodes	Boston
Michael Ivanovich Rostovtzeff	New Haven, Conn.
William Milligan Sloane	New York, N. Y.
John Osborne Sumner	Boston
Frank William Taussig	Cambridge
Frederick Jackson Turner	Madison, Wis.
Claude Halstead Van Tyne	Ann Arbor, Mich.
George Grafton Wilson	Cambridge
George Parker Winship	Charles River
Allyn Abbott Young	Cambridge

Class III., Section IV.—*Literature and the Fine Arts.*—43.

Irving Babbitt	Cambridge
George Pierce Baker	New Haven, Conn.
Frank Weston Benson	Salem
William Sturgis Bigelow	Boston
Le Baron Russell Briggs	Bournedale
Charles Allerton Coolidge	Boston
Frederick Shepherd Converse	Westwood
Samuel McChord Crothers	Cambridge
Wilberforce Eames	New York, N. Y.
Edward Waldo Emerson	Concord
William Emerson	Cambridge
Arthur Fairbanks	Hanover, N. H.
Frank Edgar Farley	Middletown, Conn.
Edward Waldo Forbes	Cambridge
Kuno Francke	Cambridge
Daniel Chester French	New York, N. Y.
Horace Howard Furness	Philadelphia, Pa.
Robert Grant	Boston

Morris Gray	Boston
Chester Noyes Greenough	Cambridge
James Kendall Hosmer	Minneapolis, Minn.
Mark Antony DeWolfe Howe	Boston
Archer Milton Huntington	New York, N. Y.
George Lyman Kittredge	Cambridge
William Coolidge Lane	Cambridge
John Ellerton Lodge	Boston
Charles Martin Tornov Loeffler	Medfield
Charles Donagh Maginnis	Brookline
Albert Matthews	Boston
Harold Murdock	Brookline
William Allan Neilson	Northampton
William Lyon Phelps	New Haven, Conn.
Arthur Kingsley Porter	Cambridge
Herbert Putnam	Washington, D. C.
Denman Waldo Ross	Cambridge
Paul Joseph Sachs	Cambridge
Ellery Sedgwick	Boston
Henry Dwight Sedgwick	Cambridge
Richard Clipston Sturgis	Boston
Charles Howard Walker	Boston
Owen Wister	Philadelphia, Pa.
George Edward Woodberry	Beverly
Charles Henry Conrad Wright	Cambridge

ASSOCIATES.—16.

Edwin Hale Abbot	Cambridge
Charles Francis Adams	Concord
Francis N. Balch	Lincoln
Charles F. Batchelder	Cambridge
William B. Cabot	Boston
John Albert Cousens	Tufts College
Henry W. Cunningham	Boston
Charles Ernest Fay	Somerville
Francis Russell Hart	Boston

William James	Cambridge
Everett Morss	Boston
Andrew James Peters	Boston
Anthony John Philpott	Arlington
Charles Henry Taylor	Boston
Edwin Sibley Webster	Brookline
Benjamin Loring Young	Weston

FOREIGN HONORARY MEMBERS.—60.

(Number limited to seventy-five.)

CLASS I.—*Mathematical and Physical Sciences.*—22.

SECTION I.—*Mathematics and Astronomy.*—6.

Arthur Stanley Eddington	Cambridge
Jacques Salomon Hadamard	Paris
Godfrey Harold Hardy	Oxford
Tullio Levi-Civita	Rome
Charles Emile Picard	Paris
Charles Jean de la Vallée Poussin	Louvain

CLASS I., SECTION II.—*Physics.*—7.

Svante August Arrhenius	Stockholm
Albert Einstein	Berlin
Sir Joseph Larmor	Cambridge
Hendrik Antoon Lorentz	Haarlem
Max Planck	Berlin
Sir Ernest Rutherford	Cambridge
Sir Joseph John Thomson	Cambridge

CLASS I., SECTION III.—*Chemistry.*—4.

Fritz Haber	Berlin
Henri Louis Le Chatelier	Paris
Wilhelm Ostwald	Leipsic
William Henry Perkin	Oxford

CLASS I., SECTION IV.—*Technology and Engineering.*—5.

Ferdinand Foch	Paris
Joseph Jacques Césaire Joffre	Paris
Maurice d'Ocagne	Paris
Vsevolod Evgenievich Timonoff	Leningrad
William Cawthorne Unwin	London

CLASS II.—*Natural and Physiological Sciences.*—21.

SECTION I.—*Geology, Mineralogy, and Physics of the Globe.*—10.

Frank Dawson Adams	Montreal
Charles Barrois	Lille
Waldemar Christofer Brögger	Christiania
Viktor Goldschmidt	Heidelberg
Albert Heim	Zurich
John Horne	Edinburgh
Emmanuel de Margerie	Paris
Gustaf Adolf Frederik Molengraaff	Delft
Sir William Napier Shaw	London
Johan Herman Lie Vogt	Trondhejm

CLASS II., SECTION II.—*Botany.*—4.

John Briquet	Geneva
Adolf Engler	Berlin
Ignatz Urban	Berlin
Hugo de Vries	Luntern

CLASS II., SECTION III.—*Zoology and Physiology.*—4.

George Albert Boulenger	Brussels
Maurice Caullery	Paris
Sir Edwin Ray Lankester	London
George Henry Falkiner Nuttall	Cambridge

CLASS II., SECTION IV.—*Medicine and Surgery.*—3.

Sir Thomas Barlow, Bart	London
Francis John Shepherd	Montreal
Sir Charles Scott Sherrington	Oxford

CLASS III.—*Moral and Political Sciences.*—17.

SECTION I.—*Theology, Philosophy, and Jurisprudence.*—3.

Rt. Hon. Arthur James Balfour, Earl of Balfour	Prestonkirk
Raymond Poincaré	Paris
Rt. Hon. Sir Frederick Pollock, Bart	London

CLASS III., SECTION II.—*Philology and Archæology.*—7.

Wilhelm Dörpfeld	Athens
Karl Friedrich Geldner	Marburg
Henri Guy	Grenoble
Hermann Georg Jacobi	Bonn
Arthur Anthony Macdonell	Oxford
Alfred Percival Maudslay	Hereford
Ramon Menendez Pidal	Madrid

CLASS III,. SECTION III.—*Political Economy and History.*—3.

Adolf Harnack	Berlin
Henri Pirenne	Ghent
Rt. Hon. Sir George Otto Trevelyan, Bart.	London

CLASS III., SECTION IV.—*Literature and the Fine Arts.*—4.

George Brandes	Copenhagen
Thomas Hardy	Dorchester
Jean Adrien Antoine Jules Jusserand	Paris
Rudyard Kipling	Burwash

STATUTES AND STANDING VOTES.

STATUTES.

Adopted November 8, 1911: *amended May* 8, 1912, *January* 8, *and May* 14, 1913, *April* 14, 1915, *April* 12, 1916, *April* 10, 1918, *May* 14, 1919, *February* 8, *April* 12, *and December* 13, 1922, *February* 14, *March* 14, *and October* 10, 1923, *and March* 10, 1926.

CHAPTER I.

The Corporate Seal.

Article 1. The Corporate Seal of the Academy shall be as here depicted:

Article 2. The Recording Secretary shall have the custody of the Corporate Seal.

See Chap. v, art. 3; chap. vi, art. 2.

CHAPTER II.

Fellows and Foreign Honorary Members and Dues.

Article 1. The Academy consists of Fellows, who are either citizens or residents of the United States of America, and Foreign Honorary Members. They are arranged in three Classes, according to the Arts and Sciences in which they are severally proficient, and each Class is divided into four Sections, namely:

Class I. *The Mathematical and Physical Sciences*

Section 1. Mathematics and Astronomy
Section 2. Physics
Section 3. Chemistry
Section 4. Technology and Engineering

Class II. *The Natural and Physiological Sciences*

Section 1. Geology, Mineralogy, and Physics of the Globe
Section 2. Botany
Section 3. Zoölogy and Physiology
Section 4. Medicine and Surgery

Class III. *The Moral and Political Sciences*

Section 1. Theology, Philosophy, and Jurisprudence
Section 2. Philology and Archæology
Section 3. Political Economy and History
Section 4. Literature and the Fine Arts

Article 2. The number of Fellows shall not exceed Six hundred, of whom not more than Four hundred shall be residents of Massachusetts, nor shall there be more than Two hundred and ten in any one Class.

Article 3. The number of Foreign Honorary Members shall not exceed Seventy-five. They shall be chosen from among citizens of foreign countries most eminent for their discoveries and attainments in any of the Classes above enumerated. There shall not be more than Twenty-five in any one Class.

ARTICLE 4. If any person, after being notified of his election as Fellow, shall neglect for six months to accept in writing, or, if a Fellow resident within fifty miles of Boston shall neglect to pay his Admission Fee, his election shall be void; and if any Fellow resident within fifty miles of Boston shall neglect to pay his Annual Dues for six months after they are due, provided his attention shall have been called to this Article of the Statutes in the meantime, he shall cease to be a Fellow; but the Council may suspend the provisions of this Article for a reasonable time.

With the previous consent of the Council, the Treasurer may dispense (*sub silentio*) with the payment of the Admission Fee or of the Annual Dues or both whenever he shall deem it advisable. In the case of officers of the Army or Navy who are out of the Commonwealth on duty, payment of the Annual Dues may be waived during such absence if continued during the whole financial year and if notification of such expected absence be sent to the Treasurer. Upon similar notification to the Treasurer, similar exemption may be accorded to Fellows subject to Annual Dues, who may temporarily remove their residence for at least two years to a place more than fifty miles from Boston.

If any person elected a Foreign Honorary Member shall neglect for six months after being notified of his election to accept in writing, his election shall be void.

See Chap. vii, art. 2.

ARTICLE 5. Every Fellow resident within fifty miles of Boston hereafter elected shall pay an Admission Fee of Ten dollars.

Every Fellow resident within fifty miles of Boston shall, and others may, pay such Annual Dues, not exceeding Fifteen dollars, as shall be voted by the Academy at each Annual Meeting, when they shall become due; but any Fellow shall be exempt from the annual payment if, at any time after his admission, he shall pay into the treasury Two hundred dollars in addition to his previous payments. Any Fellow shall also be exempt from annual dues who has paid such dues for forty years, or, having attained the age of seventy-five, has paid dues for twenty-five years.

All Commutations of the Annual Dues shall be and remain permanently funded, the interest only to be used for current expenses.

Any Fellow not previously subject to Annual Dues who takes up his residence within fifty miles of Boston, shall pay to the Treasurer within three months thereafter Annual Dues for the current year, failing which his Fellowship shall cease; but the Council may suspend the provisions of this Article for a reasonable time.

Only Fellows who pay Annual Dues or have commuted them may hold office in the Academy or serve on the Standing Committees or vote at meetings.

ARTICLE 6. Fellows who pay or have commuted the Annual Dues and Foreign Honorary Members shall be entitled to receive gratis one copy of all Publications of the Academy issued after their election.

See Chap. xi, art. 2.

ARTICLE 7. Diplomas signed by the President and the Vice-President of the Class to which the member belongs, and countersigned by the Secretaries, shall be given to Foreign Honorary Members and to Fellows on request.

ARTICLE 8. If, in the opinion of a majority of the entire Council, any Fellow or Foreign Honorary Member shall have rendered himself unworthy of a place in the Academy, the Council shall recommend to the Academy the termination of his membership; and if three-fourths of the Fellows present, out of a total attendance of not less than fifty at a Stated Meeting, or at a Special Meeting called for the purpose, shall adopt this recommendation, his name shall be stricken from the Roll.

See Chap. iii; chap. vi, art. 1; chap. x, art. 1, 7; chap. xi, art. 2.

CHAPTER III.

ELECTION OF FELLOWS AND FOREIGN HONORARY MEMBERS.

The procedure in the election of Fellows and Foreign Honorary Members shall be as follows:

Nominations to Fellowship or Foreign Honorary Membership in any Section must be signed by two Fellows of that Section, or by three Fellows of any Sections, and sent to the Corresponding Secretary ac-

companied by a statement of the qualifications of the nominee and brief biographical data.

Notice shall be sent to every Fellow not later than the fifteenth of January in each year, reminding him that all nominations must be in the hands of the Corresponding Secretary before the fifteenth of February following.

A list of the nominees, giving a brief account of each, with the names of the nominators, shall be sent to every Fellow with a request that he return the list with such confidential comments and indications of preference as he may choose to make.

All the nominations, with any comments thereon and with expressions of preference on the part of the Fellows, shall be referred to the appropriate Class Committees, which shall canvass them, and report their recommendations in writing to the Council before the Stated Meeting of the Academy in April.

Elections of Fellows and Foreign Honorary Members shall be made by the Council before the Annual Meeting in May, and announced at that meeting.

Persons nominated in any year, but not elected, may be carried over to the list of nominees for the next year at the discretion of the Council, but shall not be further continued unless renominated.

See Chap. ii; chap. vi, art. 1; chap. x, art. 1.

CHAPTER IV.

Officers.

Article 1. The Officers of the Academy shall be a President (who shall be Chairman of the Council), three Vice-Presidents (one from each Class), a Corresponding Secretary (who shall be Secretary of the Council), a Recording Secretary, a Treasurer, a Librarian, and an Editor, all of whom shall be elected by ballot at the Annual Meeting, and shall hold their respective offices for one year, and until others are duly chosen and installed.

There shall be also twelve Councillors, one from each Section of each Class. At each Annual Meeting three Councillors, one from each Class, shall be elected by ballot to serve for the full term of four

years and until others are duly chosen and installed. The same Fellow shall not be eligible for two successive terms.

The Councillors, with the other officers previously named, and the Chairman of the House Committee, *ex officio*, shall constitute the Council.

See Chap. xi, art. 1.

Article 2. If any officer be unable, through death, absence, or disability, to fulfil the duties of his office, or if he shall resign, his place may be filled by the Council in its discretion for any part or the whole of the unexpired term.

Article 3. At the Stated Meeting in March, the President shall appoint a Nominating Committee of three Fellows having the right to vote, one from each Class. This Committee shall prepare a list of nominees for the several offices to be filled, and for the Standing Committees, and file it with the Recording Secretary not later than four weeks before the Annual Meeting.

See Chap. vi, art. 2.

Article 4. Independent nominations for any office, if signed by at least twenty Fellows having the right to vote, and received by the Recording Secretary not less than ten days before the Annual Meeting, shall be inserted in the call therefor, and shall be mailed to all the Fellows having the right to vote.

See Chap. vi, art. 2.

Article 5. The Recording Secretary shall prepare for use in voting at the Annual Meeting a ballot containing the names of all persons duly nominated for office.

CHAPTER V.

The President.

Article 1. The President, or in his absence the senior Vice-President present (seniority to be determined by length of continuous fellowship in the Academy), shall preside at all meetings of the Acad-

emy. In the absence of all these officers, a Chairman of the meeting shall be chosen by ballot.

ARTICLE 2. Unless otherwise ordered, all Committees which are not elected by ballot shall be appointed by the presiding officer.

ARTICLE 3. Any deed or writing to which the Corporate Seal is to be affixed, except leases of real estate, shall be executed in the name of the Academy by the President or, in the event of his death, absence, or inability, by one of the Vice-Presidents, when thereto duly authorized.

See Chap. ii, art. 7; chap. iv, art. 1, 3; chap. vi, art. 2; chap. vii, art. 1; chap. x, art. 6; chap. xi, art. 1, 2; chap. xii, art. 1.

CHAPTER VI.

THE SECRETARIES.

ARTICLE 1. The Corresponding Secretary shall conduct the correspondence of the Academy and of the Council, recording or making an entry of all letters written in its name, and preserving for the files all official papers which may be received. At each meeting of the Council he shall present the communications addressed to the Academy which have been received since the previous meeting, and at the next meeting of the Academy he shall present such as the Council may determine.

He shall notify all persons who may be elected Fellows or Foreign Honorary Members, send to each a copy of the Statutes, and on their acceptance issue the proper Diploma. He shall also notify all meetings of the Council; and in case of the death, absence, or inability of the Recording Secretary he shall notify all meetings of the Academy.

Under the direction of the Council, he shall keep a List of the Fellows and Foreign Honorary Members, arranged in their several Classes and Sections. It shall be printed annually and issued as of the first day of July.

See Chap. ii, art. 7; chap. iii, art. 2, 3; chap. iv, art. 1; chap. x, art. 6; chap. xi, art. 1; chap. xii, art. 1.

ARTICLE 2. The Recording Secretary shall have the custody of the Charter, Corporate Seal, Archives, Statute-Book, Journals, and all literary papers belonging to the Academy.

Fellows borrowing such papers or documents shall receipt for them to their custodian.

The Recording Secretary shall attend the meetings of the Academy and keep a faithful record of the proceedings with the names of the Fellows present; and after each meeting is duly opened, he shall read the record of the preceding meeting.

He shall notify the meetings of the Academy to each Fellow and by mail at least seven days beforehand, and in his discretion may also cause the meetings to be advertised; he shall apprise Officers and Committees of their election or appointment, and inform the Treasurer of appropriations of money voted by the Academy.

After all elections, he shall insert in the Records the names of the Fellows by whom the successful nominees were proposed.

He shall send the Report of the Nominating Committee in print to every Fellow having the right to vote at least three weeks before the Annual Meeting.

See Chap. iv, art. 3.

In the absence of the President and of the Vice-Presidents he shall, if present, call the meeting to order, and preside until a Chairman is chosen.

See Chap. i; chap. ii, art. 7; chap. iv, art. 3, 4, 5; chap. x, art. 6; chap. xi, art. 1, 2; chap. xii, art. 1, 3.

ARTICLE 3. The Secretaries, with the Editor, shall have authority to publish such of the records of the meetings of the Academy as may seem to them likely to promote its interests.

CHAPTER VII.

THE TREASURER AND THE TREASURY.

ARTICLE 1. The Treasurer shall collect all money due or payable to the Academy, and all gifts and bequests made to it. He shall pay all bills due by the Academy, when approved by the proper officers, except those of the Treasurer's office, which may be paid without such approval; in the name of the Academy he shall sign all leases of real estate; and, with the written consent of a member of the Committee

on Finance, he shall make all transfers of stocks, bonds, and other securities belonging to the Academy, all of which shall be in his official custody.

He shall keep a faithful account of all receipts and expenditures, submit his accounts annually to the Auditing Committee, and render them at the expiration of his term of office, or whenever required to do so by the Academy or the Council.

He shall keep separate accounts of the income of the Rumford Fund, and of all other special Funds, and of the appropriation thereof, and render them annually.

His accounts shall always be open to the inspection of the Council.

Article 2. He shall report annually to the Council at its March meeting on the expected income of the various Funds and from all other sources during the ensuing financial year. He shall also report the names of all Fellows who may be then delinquent in the payment of their Annual Dues.

Article 3. He shall give such security for the trust reposed in him as the Academy may require.

Article 4. With the approval of a majority of the Committee on Finance, he may appoint an Assistant Treasurer to perform his duties, for whose acts, as such assistant, he shall be responsible; or, with like approval and responsibility, he may employ any Trust Company doing business in Boston as his agent for the same purpose, the compensation of such Assistant Treasurer or agent to be fixed by the Committee on Finance and paid from the Funds of the Academy.

Article 5. At the Annual Meeting he shall report in print all his official doings for the preceding year, stating the amount and condition of all the property of the Academy entrusted to him, and the character of the investments.

Article 6. The Financial Year of the Academy shall begin with the first day of April.

Article 7. No person or committee shall incur any debt or liability in the name of the Academy, unless in accordance with a

previous vote and appropriation therefor by the Academy or the Council, oı sell or otherwise dispose of any property of the Academy, except cash or invested funds, without previous consent and approval of the Council.

See Chap. ii, art. 4, 5; chap. vi, art. 2; chap. x, art. 6; chap. xi, art. 1, 2, 3; chap. xii, art. 1.

CHAPTER VIII.

The Librarian and the Library.

Article 1. The Librarian shall have charge of the printed books, keep a correct catalogue thereof, and provide for their delivery from the Library.

At the Annual Meeting, as Chairman of the Committee on the Library, he shall make a Report on its condition.

Article 2. In conjunction with the Committee on the Library he shall have authority to expend such sums as may be appropriated by the Academy for the purchase of books, periodicals, etc., and for defraying other necessary expenses connected with the Library.

Article 3. All books procured from the income of the Rumford Fund or of other special Funds shall contain a book-plate expressing the fact.

Article 4. Books taken from the Library shall be receipted for to the Librarian or his assistant.

Article 5. Books shall be returned in good order, regard being had to necessary wear with good usage. If any book shall be lost or injured, the Fellow to whom it stands charged shall replace it by a new volume or by a new set, if it belongs to a set, or pay the current price thereof to the Librarian, whereupon the remainder of the set, if any, shall be delivered to the Fellow so paying, unless such remainder be valuable by reason of association.

Article 6. All books shall be returned to the Library for examination at least one week before the Annual Meeting.

ARTICLE 7. The Librarian shall have the custody of the Publications of the Academy. With the advice and consent of the President, he may effect exchanges with other associations.

See Chap. ii, art. 6; chap. xi, art. 1, 2.

CHAPTER IX.

THE EDITOR AND THE PUBLICATIONS.

ARTICLE 1. The Editor shall have charge of the conduct through the press of the Proceedings and the Memoirs, and all correspondence relative thereto, and shall have power to fix the price at which individual numbers of the Proceedings and the Memoirs are sold.

ARTICLE 2. In conjunction with the Committee of Publication, he shall have authority to expend such sums as may be appropriated by the Academy for printing the publications and for defraying other expenses therewith connected.

ARTICLE 3. All publications which are financed in whole or in part from the income of the Rumford Fund or from the income of other special funds, and all publications of work done with the aid of the Rumford Fund or other special funds, shall contain a conspicuous statement of this fact.

ARTICLE 4. Two hundred extra copies of each paper printed in the Proceedings or Memoirs shall be placed at the disposal of the author without charge.

If, on account of the number of communications offered for publication, it shall be necessary to decline for publication communications otherwise acceptable, members of the Academy shall be given preference in each of the several Classes over non-members; but whenever it shall be necessary to exercise this preference, the Editor shall inform the Council of the fact.

See Chap. iv, art. 1; chap. vi, art. 3; chap. x, art. 6; chap. xi, art. 4.

CHAPTER X.

The Council.

Article 1. The Council shall exercise a discreet supervision over all nominations and elections to membership, and in general supervise all the affairs of the Academy not explicitly reserved to the Academy as a whole or entrusted by it or by the Statutes to standing or special committees.

It shall consider all nominations duly sent to it by any Class Committee, and act upon them in accordance with the provisions of Chapter III.

With the consent of the Fellow interested, it shall have power to make transfers between the several Sections, reporting its action to the Academy.

See Chap. iii, art. 2, 3; chap. xi, art. 1.

Article 2. Seven members shall constitute a quorum.

Article 3. It shall establish rules and regulations for the transaction of its business, and provide all printed and engraved blanks and books of record.

Article 4. It shall act upon all resignations of officers, and all resignations and forfeitures of Fellowship; and cause the Statutes to be faithfully executed.

It shall appoint all agents and subordinates not otherwise provided for by the Statutes, prescribe their duties, and fix their compensation. They shall hold their respective positions during the pleasure of the Council.

Article 5. It may appoint, for terms not exceeding one year, and prescribe the functions of, such committees of its numbers, or of the Fellows of the Academy, as it may deem expedient, to facilitate the administration of the affairs of the Academy or to promote its interests.

Article 6. At its March meeting it shall receive reports from the President, the Secretaries, the Treasurer, and the Standing Commit-

tees, on the appropriations severally needed for the ensuing financial year. At the same meeting the Treasurer shall report on the expected income of the various Funds and from all other sources during the same year.

A report from the Council shall be submitted to the Academy, for action, at the March meeting, recommending the appropriation which in the opinion of the Council should be made.

On the recommendation of the Council, special appropriations may be made at any Stated Meeting of the Academy, or at a Special Meeting called for the purpose.

See Chap. xi, art. 3.

Article 7. After the death of a Fellow or Foreign Honorary Member, it shall appoint a member of the Academy to prepare a biographical notice for publication in the Proceedings.

Article 8. It shall report at every meeting of the Academy such business as it may deem advisable to present.

See Chap. ii, art. 4, 5, 8; chap. iv, art. 1, 2; chap. vi, art. 1; chap. vii, art. 1; chap. xii, art. 1, 4.

CHAPTER XI.

Standing Committees.

Article 1. The Class Committee of each Class shall consist of the Vice-President, who shall be chairman, and the four Councillors of the Class, together with such other officer or officers annually elected as may belong to the Class. It shall consider nominations to Fellowship in its own Class, and report in writing to the Council such as may receive at a Class Committee Meeting a majority of the votes cast, provided at least three shall have been in the affirmative.

See Chap. iii, art. 2.

Article 2. At the Annual Meeting the following Standing Committees shall be elected by ballot to serve for the ensuing year:

(i) *The Committee on Finance,* to consist of three Fellows, who, through the Treasurer, shall have full control and management of the

funds and trusts of the Academy, with the power of investing the funds and of changing the investments thereof in their discretion.

See Chap. iv, art. 3; chap. vii, art. 1, 4; chap. x, art. 6.

(ii) *The Rumford Committee,* to consist of seven Fellows, who shall report to the Academy on all applications and claims for the Rumford Premium. It alone shall authorize the purchase of books, publications and apparatus at the charge of the income from the Rumford Fund, and generally shall see to the proper execution of the trust.

See Chap. iv, art. 3; chap. x, art. 6.

(iii) *The Cyrus Moors Warren Committee,* to consist of seven Fellows, who shall consider all applications for appropriations from the income of the Cyrus Moors Warren Fund, and generally shall see to the proper execution of the trust.

See Chap. iv, art. 3; chap. x, art. 6.

(iv) *The Committee of Publication,* to consist of the Editor, *ex officio,* as Chairman, and three other Fellows, one from each Class, to whom all communications submitted to the Academy for publication shall be referred, and to whom the printing of the Proceedings and the Memoirs shall be entrusted.

It shall fix the price at which volumes of the publications shall be sold; but Fellows may be supplied at half price with volumes which may be needed to complete their sets, but which they are not entitled to receive gratis.

It shall determine when the pressure of material offered for publication makes it necessary to give preference to members of the Academy as compared with non-members, or to give priority to certain members as compared with others, and to what extent this preference or priority shall be applied in each of the three Classes, to the end that a proper balance of the facilities of publication with respect to subject matter and authors may be maintained.

See Chap. iv, art. 3; chap. vi, art. 1, 3; chap. ix; chap. x, art. 6.

(v) *The Committee on the Library,* to consist of the Librarian, *ex officio,* as Chairman, and three other Fellows, one from each Class,

who shall examine the Library and make an annual report on its condition and management.

See Chap. iv, art. 3; chap. viii, art. 1, 2; chap. x, art. 6.

(vi) *The House Committee,* to consist of three Fellows, who shall have charge of all expenses connected with the House, including the general expenses of the Academy not specifically assigned to the care of other Committees or Officers.

See Chap. iv, art. 1, 3; chap. x, art. 6.

(vii) *The Committee on Meetings,* to consist of the President, the Recording Secretary, and three other Fellows, who shall have charge of plans for meetings of the Academy.

See Chap. iv, art. 3; chap. x, art. 6.

(viii) *The Auditing Committee,* to consist of two Fellows, who shall audit the accounts of the Treasurer, with power to employ an expert and to approve his bill.

See Chap. iv, art. 3; chap. vii, art. 1; chap. x, art. 6.

ARTICLE 3. The Standing Committees shall report annually to the Council in March on the appropriations severally needed for the ensuing financial year; and all bills incurred on account of these Committees, within the limits of the several appropriations made by the Academy, shall be approved by their respective Chairmen.

In the absence of the Chairman of any Committee, bills may be approved by any member of the Committee whom he shall designate for the purpose.

See Chap. vii, art. 1, 7; chap. x, art. 6.

CHAPTER XII.

MEETINGS, COMMUNICATIONS, AND AMENDMENTS.

ARTICLE 1. There shall be annually eight Stated Meetings of the Academy, namely, on the second Wednesday of October, November, December, January, February, March, April, and May. Only at these meetings, or at adjournments thereof regularly notified, or at

Special Meetings called for the purpose, shall appropriations of money be made or amendments of the Statutes or Standing Votes be effected.

The Stated Meeting in May shall be the Annual Meeting of the Corporation.

Special Meetings shall be called by either of the Secretaries at the request of the President, of a Vice-President, of the Council, or of ten Fellows having the right to vote; and notifications thereof shall state the purpose for which the meeting is called.

A meeting for receiving and discussing literary or scientific communications may be held on the fourth Wednesday of each month, excepting July, August, and September; but no business shall be transacted at said meetings.

ARTICLE 2. Twenty Fellows having the right to vote shall constitute a quorum for the transaction of business at Stated or Special Meetings. Fifteen Fellows shall be sufficient to constitute a meeting for literary or scientific communications and discussions.

ARTICLE 3. Upon the request of the presiding officer or the Recording Secretary, any motion or resolution offered at any meeting shall be submitted in writing.

ARTICLE 4. No report of any paper presented at a meeting of the Academy shall be published by any Fellow without the consent of the author; and no report shall in any case be published by any Fellow in a newspaper as an account of the proceedings of the Academy without the previous consent and approval of the Council. The Council, in its discretion, by a duly recorded vote, may delegate its authority in this regard to one or more of its members.

ARTICLE 5. No Fellow shall introduce a guest at any meeting of the Academy until after the business has been transacted, and especially until after the result of the balloting upon nominations has been declared.

ARTICLE 6. The Academy shall not express its judgment on literary or scientific memoirs or performances submitted to it, or included in its Publications.

ARTICLE 7. All proposed Amendments of the Statutes shall be referred to a committee, and on its report, at a subsequent Stated Meeting or at a Special Meeting called for the purpose, two-thirds of the ballot cast, and not less than twenty, must be affirmative to effect enactment.

ARTICLE 8. Standing Votes may be passed, amended, or rescinded at a Stated Meeting, or at a Special Meeting called for the purpose, by a vote of two-thirds of the members present. They may be suspended by a unanimous vote.

See Chap. ii, art. 5, 8; chap. iii; chap. iv, art. 3, 4, 5; chap. v, art. 1; chap. vi, art. 1, 2; chap. x, art. 8.

STANDING VOTES.

1. Communications of which notice has been given to either of the Secretaries shall take precedence of those not so notified.

2. Fellows may take from the Library six volumes at any one time, and may retain them for three months, and no longer. Upon special application, and for adequate reasons assigned, the Librarian may permit a larger number of volumes, not exceeding twelve, to be drawn from the Library for a limited period.

3. Works published in numbers, when unbound, shall not be taken from the Hall of the Academy without the leave of the Librarian.

4. The Council, under such rules respecting nominations as it may prescribe, may elect as Associates of the Academy a limited number of men of mark in affairs or of distinguished service in the community.

Associates shall be entitled to the same privileges as Fellows, but shall not have the right to vote.

The admission fee and annual dues of Associates shall be the same as those of Fellows residing within fifty miles of Boston.

5. Communications offered for publication in the Proceedings or Memoirs of the Academy shall not be accepted for publication before the author shall have informed the Committee on Meetings of his readiness, either himself or through some agent, to use such time as the Committee may assign him at such meeting as may be convenient both to him and to the Committee, for the purpose of presenting to the Academy a general statement of the nature and significance of the results contained in his communication.

RUMFORD PREMIUM.

In conformity with the terms of the gift of Sir Benjamin Thompson Count Rumford, of a certain Fund to the American Academy of Arts and Sciences, and with a decree of the Supreme Judicial Court of Massachusetts for carrying into effect the general charitable intent and purpose of Count Rumford, as expressed in his letter of gift, the Academy is empowered to make from the income of the Rumford Fund, as it now exists, at any Annual Meeting, an award of a gold and a silver medal, being together of the intrinsic value of three hundred dollars, as a Premium to the author of any important discovery or useful improvement in light or heat, which shall have been made and published by printing, or in any way made known to the public, in any part of the continent of America, or any of the American islands; preference always being given to such discoveries as, in the opinion of the Academy, shall tend most to promote the good of mankind; and, if the Academy sees fit, to add to such medals, as a further Premium for such discovery and improvement, a sum of money not exceeding three hundred dollars.

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Date of issue.	Date of issue.	Date of issue.
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